CHAPTER 3

PRESSURIZATION AND AIR-CONDITIONING SYSTEMS

Terminal Objective: Upon completion of this chapter, you will be able to recognize the operational and component differences between air cycle and refrigerant cycle air-conditioning systems (ACS).

Transferring a human being from his natural environment on the earth's surface to the environment existing at 40,000 feet places him in surroundings in which he cannot survive without artificial aids. Even at half that altitude, breathing becomes very rapid; and above 25,000 feet unconsciousness occurs, quickly followed by death. A brief study of the earth's atmosphere tells us why this condition exists.

STRUCTURE OF THE ATMOSPHERE

Learning Objective: Recognize the affect high altitude flight could have on flight personnel because of decreased atmospheric pressure.

The envelope of atmosphere surrounding the earth is a gaseous mixture consisting chiefly of nitrogen and oxygen. There are traces of other gases, but they have no significance as far as body functions are concerned. Chemical analysis has shown that the proportions of nitrogen and oxygen are constant throughout the thickness of the atmosphere, up through 200,000 feet or more.

ATMOSPHERIC PRESSURE

Although the chemical content of the atmosphere remains fairly constant, the density (mass per unit volume) of the atmosphere varies with altitude. At 18,000 feet the density is about one-half of the density at sea level, and at 36,000 feet it is only about one-fourth of the density at sea level. The atmospheric pressure also varies with the altitude. The pressure exerted by the atmosphere may be compared to the pressure of a column of water. If holes are made in the container of the column, the force with which the water spurts out of the upper holes will be considerably less than that at the bottom of the column. Similarly, the pressure exerted by the atmosphere is much greater near the surface of the earth than it is at high altitudes. For example, the pressure of the atmosphere at sea level is 14.7 psi, while the pressure at 40,000 feet above sea level is 2.72 psi, and at 60,000 feet is 1 psi.

As an aircraft ascends to higher altitude, the resulting decrease in atmospheric pressure may affect flight personnel in several ways. The most noticeable effect is in breathing.

Breathing is a mechanical process that depends heavily on atmospheric pressure. When a person inhales, he automatically raises his ribs and depresses his diaphragm so that the chest cavity is enlarged. This reduces the air pressure within the cavity below that of the atmosphere outside. Air is thus pushed into the lungs. When he exhales, he reduces the chest cavity, increasing the pressure within it. This pushes the air out of the lungs.

When low atmospheric pressures are encountered, the lungs are not filled so completely when inhaling. With lower density, a person gets fewer molecules of air in each breath. If he gets fewer molecules of air in each breath, he also gets fewer molecules of oxygen, and no person can live unless he gets a sufficient amount of oxygen.

This problem may be solved up to certain altitudes by the proper use of oxygen equipment; however, at extremely high altitudes (above 35,000 feet), the atmospheric pressure is so low that the pressure of the blood and other liquids in the body are no longer balanced. The human body then tends to burst. In some cases, blood vessels near the surface may burst, causing hemorrhages in the ears, eyes, and breathing passages.

The outside air temperature also changes with altitude. For example, at approximately 18,000 feet the outside air temperature will be – 4°F (– 20°C), and at approximately 37,000 feet the outside air temperature will be – 67°F (– 55°C). Above 37,000 feet the air continues to thin, but the air temperature will remain constant for several miles and then begin to rise slowly. Thus, the lowest outside air temperature to be encountered by an aircraft would occur at a height of about 7 miles.

NOTE: The conversion formula for converting Fahrenheit to Celsius (centigrade) is $\frac{5}{9}$ (F-32).

For example, – 4°F is converted as

$$\frac{5}{9}(-4 - 32) = \frac{5}{9} \text{ of } -36 = -20\,°\text{C}.$$

Conversion of a Celsius temperature to a Fahrenheit reading is accomplished using the following formula:

$$\frac{9}{5}°\text{C} + 32$$

For example, – 55°C is converted as

$$\frac{9}{5}(-55) + 32 = -99 + 32 = -67\,°\text{F}.$$

Remember not to drop the + and – signs when converting.

These variations in outside air temperature and atmospheric pressure are considered by the aircraft manufacturer when designing the aircraft.

ATMOSPHERIC CONSIDERATIONS

Pressurization and air conditioning of aircraft are necessary at high altitudes. With operational ceilings now in excess of 50,000 feet, flight personnel, and in some cases aircraft components, are supplied with an artificial means of maintaining a reasonable pressure around the entire body and/or equipment. This is done be sealing off the entire cabin/cockpit and any equipment area that may require pressurization and maintaining an inside air pressure equivalent to that at substantially lower altitudes. This is known as the pressurized cabin, cockpit, or compartment, as applicable.

In addition to pressurizing them, the cabin, cockpit, and some compartments are also air-conditioned if the aircraft is to fly at high speeds. This requirement is partly due to the difference in temperatures at various altitudes and also aerodynamic heating. For example, an aircraft flying at supersonic speeds at an altitude of 35,000 feet may generate a temperature on its skin of 200°F, and twice that temperature at altitudes near sea level.

In addition to aerodynamic heating, other factors affecting cabin/cockpit temperatures are engine heat, heat from the sun (solar heat), heat from the electrical units, and heat from the body. Through research and tests, it was determined that the average total temperature of these five heat sources will raise the cabin/cockpit temperature to approximately 190°F (88°C). Through experiments it was determined that the maximum temperature that a person can withstand and maintain efficiency for extended periods is 80°F (27°C); therefore, air conditioning of the cabin/cockpit area is just as essential as pressurization. Under low-speed operating conditions at low temperature, cabin/cockpit heating may be required.

The proper operation of much of todays aircraft electronic equipment is also dependent on maintaining a reasonable operating temperature that will prolong the life of various components. In most cases equipment cooling is provided by teeing off with ducting from the cabin/cockpit system. On other aircraft a separate cooling system may be used primarily for equipment cooling.

ENVIRONMENTAL CONTROL SYSTEMS

Learning Objective: Recognize the need for environmental control systems.

The combined pressurization and air conditioning of the cabin is the function of the aircraft pressurization and air-conditioning system; a system now in all naval aircraft. The inspection and maintenance of this system is one of the important duties of the AME. There are five requirements necessary for the successful functioning of a pressurization and air-conditioning system.

1. The cabin must be designed to withstand the necessary pressure differential. This is

primarily an airframe engineering and manufacturing problem.

2. There must be a means of limiting the maximum pressure differential to which the cabin walls will be subjected. This is provided by the cabin safety valve.

3. The aircraft must have an adequate supply of compressed air. This is provided through the compressor section of the jet engine. A separate compressor or supercharger is used on aircraft having reciprocating engines. On all jet aircraft, the air is taken directly from the compressor section of the jet engine. This is generally referred to as bleed air.

4. There must be a means of cooling the bleed air before it enters the cabin. This is provided by an aircraft refrigeration unit.

5. There must be a means of controlling the cabin pressure. This is provided by the cabin pressure regulator, which regulates the outflow of air from the cabin.

In addition to the major components, various valves, controls, and other allied units are necessary to complete an aircraft pressurization and air-conditioning system. The design, construction, and use of these components may vary somewhat with different manufacturers; however, the systems on all jet aircraft operate on the same principles. The system used as an example in this text is in the F-18 aircraft.

The environmental control systems of most aircraft include cabin air conditioning and pressurization, equipment cooling, defogging, windshield washing and rain removal, and equipment pressurization subsystems.

Coverage in this section is limited to air cycle cabin and equipment pressurization and air conditioning.

BLEED-AIR SYSTEM

Bleed air is supplied by the last compressor section of each engine (fig. 3-1, a foldout at the end of this chapter). This bleed air flows from the engines through two engine bleed-air pressure regulation and shutoff valves. The valves are spring-loaded closed when the system is not in use. When air conditioning is selected, the valves open and regulate bleed air to a predetermined pressure. The bleed air then passes through two engine bleed-air check valves, which prevent reverse flow from one engine to the other. At this point the bleed air from both engines enters a common duct and flows through the engine bleed-air secondary pressure-regulating and shutoff valve. This valve is spring-loaded open and regulates the pressure of the combined flow of bleed air from both engines. The regulated bleed air then flows into the primary heat exchanger of the ACS.

There are two overpressure switches (primary and secondary) incorporated in the system to prevent overpressure damage to system components in case of a pressure regulator malfunction. An air isolation valve is located in the system to provide a means of providing bleed air to the ACS when required and during cross starting of engines. These bleed-air components are discussed in the following paragraphs.

Engine Bleed-Air Pressure Regulation and Shutoff Valve

These two valves (fig. 3-1) act as system shutoff valves when air conditioning is not required. They are spring-loaded closed. When air conditioning is selected, an electric solenoid is energized, which unseats a poppet from the vent line. As air flows from the engine, a line downstream of the butterfly valve routes a small amount of the bleed air to the butterfly diaphragm. This air is called control air since its action on the diaphragm is the controlling force for the valve. As pressure builds on the diaphragm, it overcomes spring pressure holding the butterfly closed and the valve opens. As the bleed air passes through the valve, another line upstream of the butterfly routes bleed air to the regulator portion of the valve. As pressure builds and overcomes spring pressure, a poppet is reseated, allowing some of the control air pressure from the open side of the butterfly diaphragm to bleed off. Spring pressure can now start closing the butterfly, thus lowering the bleed-air pressure downstream of the butterfly. In this manner bleed-air pressure is controlled to 75 ± 15 psi.

Engine Bleed-Air Check Valve

These dual-flapper check valves are located downstream of the pressure regulator and shutoff valves (fig. 3-1). They prevent cross-flow of bleed air from one engine to the opposite engine in the event of single engine operation.

Engine Bleed-Air Secondary Pressure-Regulating And Shutoff Valve

This valve is located in the common ducting upstream of the bleed-air check valves (fig. 3-1).

It operates in the same manner as the two engine pressure regulation and shutoff valves with the following exceptions. The valve is normally spring-loaded open and regulates at a set pressure of 110 ± 5 psi, thus acting as a safety regulator in the event one or both engine regulators fail and allow pressure to build up in excess of system design.

Primary Bleed-Air Overpressure Switch

This switch is located downstream of the bleed-air check valves (fig. 3-l). This switch activates at 250 psi and provides a signal to the Digital Display Indicator (DDI). The DDI is located in the nosewheel well of the aircraft and stores failed systems/component code numbers. These code numbers are used in troubleshooting the aircraft after flight, and aids in pinpointing malfunctions rapidly.

Secondary Bleed-Air Overpressure Switch

The pressure switch is mounted in the ducting downstream of the secondary bleed-air regulator. If bleed-air pressure at this point exceeds 150±10 psi, the overpressure switch provides a signal to close the three pressure regulator and shutoff valves as well as store a failed system code number in the DDI.

Air Isolation Valve

The sir isolation valve serves two purposes. First, it is used to cross start engines. After starting one engine on the auxiliary power unit (APU) or ground air, with the APU switch in the off position, the engine crank switch will automatically open the air isolation valve when starting the other engine. Bleed air from the engine running is routed through the air isolation valve to the engine starter control valve (fig. 3-1) of the engine to be started. As the engine accelerates to a self-sustaining speed, the switch automatically returns to the off position. The air isolation valve is then closed by spring pressure.

The air isolation valve can also be used to route APU air to augment the bleed-air supplv to the air-conditioning system at times when engine output is low. This could be when waiting to launch, with engines at idle power and air temperatures high and humid.

BLEED-AIR LEAK DETECTION

The bleed-air leak detection system warns the pilot of a leak in the bleed-air distribution lines or shuts down the system, as necessary. The leak detection system consists of a control unit and nine detectors. When one of the detectors senses an overheat condition, it sends a signal through the control unit. The control unit signals the respective bleed-air pressure regulator to close and lights a warning light on the advisory panel in the cockpit, giving the location of the detector sensing the overheat condition.

AIR CYCLE AIR-CONDITIONING SYSTEMS

Learning Objective: Recognize the operating principles and components of air cycle air-conditioning systems (ACS).

Most naval aircraft are designed with an air cycle ACS because it is efficient for the weight and space required and is relatively trouble free. The name air cycle or air-to-air comes from the principle of cooling the air without the use of refrigerants by compression and expansion of hot bleed air. The F-18 air cycle ACS is an example of this type system (fig. 3-2, a foldout at the end of this chapter).

SYSTEM OPERATION

The air cycle ACS was designed to operate by passing hot engine bleed air through the primary heat exchanger where ram air, forced across the heat exchanger by the aircrafts forward motion, absorbs heat from the bleed air, reducing the air temperature. On the ground and during low-speed operation, ram air is pulled across the heat exchangers by hot air ejected into the heat exchanger exit ducts by the primary and secondary heat exchanger ejectors. The cooled bleed air then passes to the flow modulating system pressure regulator valve where, controlled by electrical and pneumatic sensors, the downstream pressure is maintained by regulator modulation. The air enters the compressor end of the refrigeration turbine/compressor assembly where it is compressed to approximately twice its inlet temperature. The compressed air enters the secondary heat exchanger where ram air absorbs the heat acquired through compression. From the secondary heat exchanger, air enters the refrigeration cycle. The cycle is made up of a reheater heat exchanger and a condenser/vent suit heat exchanger and water extractor, which removes 90 percent of the moisture content through repeated heating and cooling. The conditioned dry air is transported to the turbine end of the refrigeration turbine/compressor assembly where it is cooled by rapid expansion. Both the turbine and compressor are protected from overheat damage by the turbine and compressor protective temperature sensors. As the cold dry air leaves the turbine, it is mixed with warm air from the environmental control and related systems, and then it is routed to cockpit and avionics compartments to satisfy environmental control requirements. Air cycle ACS components are discussed in the following paragraphs.

Primary Heat Exchanger

The primary heat exchanger (fig. 3-2) is a cross-flow, air-to-air heat exchanger that uses ram air to initially cool hot engine bleed air. It operates on the same principle as the radiator in an automobile with the bleed air replacing the liquid. Hot bleed air is transported through the heat exchanger core where ram air, forced across the core by aircraft forward motion, absorbs the heat from the bleed air, reducing the air temperature. During ground and low-speed operation, cooling air is pulled across the heat exchanger core by ejecting hot air into the heat exchanger exit duct. The ejected air is controlled by the primary ejector valve in response to signals from the Air Data Computer (ADC). The cooled air exiting the heat exchanger is divided into two ducts that provide air at varying temperatures for use in related systems. The temperature difference occurs because of the distance the bleed air travels through the heat exchanger core.

Primary Ejector Valve

The primary ejector valve is a normally open, in-line poppet, pneumatically actuated, solenoid-controlled shutoff valve. The valve controls the flow of bleed air to the primary heat exchanger ejector in the primary heat exchanger exit duct. The hot bleed air flowing through the ejector nozzles causes an area of low pressure to form at that point. This causes ambient air to flow across the core of the heat exchanger from the high pressure side to the area of low pressure. The valve is controlled by an electrical signal from the ADC. At airspeeds below 100 knots, the ADC provides an electrical ground that energizes the primary ejector control relay to remove power from the valve solenoid, allowing differential pressure to hold the valve open. At airspeeds above 100 knots, the ADC ground is lost. This de-energizes the primary ejector control relay to apply power to the valve solenoid, allowing spring tension to close the valve.

Flow Modulating System Pressure Regulator Valve

The flow modulating system pressure regulator valve is a combination butterfly, modulating valve, and solenoid shutoff valve. The modulating valve is normally open and pneumatically actuated. The valve is in the distribution ducting between the primary heat exchanger and the refrigeration turbine/compressor assembly. The valve uses electrical signals from the avionics temperature/flow sensor by way of the ACS temperature/flow controller to modulate downstream pressure. The valve is also connected pneumatically to the turbine and compressor protective temperature sensors, which override all other valve functions to close the valve to protect the refrigeration turbine/compressor assembly from heat damage during overtemperature conditions. The solenoid shutoff is controlled by the environmental control system (ECS) mode switch, which allows the valve to be opened or closed by dumping control air from the butterfly diaphragm chamber. The valve also includes a visual position indicator. The indicator is built into the valve housing and shows the position of the butterfly.

Avionics Ram Air Servo

The avionics ram air servo monitors the differential pressure of bleed air upstream and downstream of the flow modulating system pressure regulator valve. If the upstream pressure is less than 35 psi and the differential pressure is less than 10 psi, the avionics ram air servo drives the avionics ram air valve open. If downstream pressure is less than 4 psi, the avionics ram air servo drives the avionics ram air valve open. The operation of this valve, though not a part of the ACS, ensures that avionics will receive sufficient cooling air in the event of a low or no airflow condition from the ACS.

Compressor Protective Temperature Sensor

The compressor protective temperature sensor is a pneumatic bleed off thermostat, which contains a fluid-filled sensing element and a ball metering valve. The unit is in the duct upstream of the turbine/compressor assembly. The thermostat is connected pneumatically to the flow modulation system pressure regulator valve and responds to air temperature. As the air temperature increases, the fluid in the sensing element expands and opens the ball metering valve, which vents control pressure from the flow modulating valve. This causes the regulator to close, decreasing the bleed-air flow, which slows the rpm of the turbine assembly, thus protecting it from damage because of overtemperature.

Turbine Protective Temperature Sensor

The turbine protective temperature sensor is identical to the compressor protective temperature sensor except for calibrated temperature and location. The turbine protective temperature sensor is in the turbine inlet duct.

Secondary Heat Exchanger

The secondary heat exchanger is a cross-flow, air-to-air heat exchanger. Hot, high-pressure air, discharged from the compressor end of the refrigeration turbine/compressor assembly, is transported through the core of the heat exchanger where ram air, augmented by water spray, is forced across the core by aircraft forward motion, absorbing heat from the air and reducing the air temperature. During ground and low-speed operation, cooling air is pulled across the heat exchanger core by ejecting hot air into the heat exchanger exit duct. The ejected air is controlled by the secondary ejector valve in response to signals from the ADC.

Secondary Ejector Valve

The secondary ejector valve is a normally open in-line poppet, pneumatically actuated, solenoid-controlled shutoff valve. The valve controls the flow of bleed air to the secondary heat exchanger ejector in the secondary heat exchanger exit duct. The valve is controlled by an electrical signal from the ADC. At airspeeds below 165 knots, this valve operates on the same principle as the primary ejector valve.

Water Spray Nozzle

The water spray nozzle is used to form a mist in the secondary heat exchanger ram air inlet, which aids in cooling the air. Water is extracted from the conditioned air in the water extractor. The water is transported to the water spray nozzle into the secondary heat exchanger ram air inlet. The nozzle directs a jet of water onto a pin, forming a fine sheet of water before breaking up into a mist. The mist is forced across the heat exchanger with the ram airflow.

Reheater Heat Exchanger

The reheater heat exchanger is a single-pass, cross-flow, air-to-air heat exchanger. The reheater heat exchanger cools air from the secondary heat exchanger before moisture removal in the condenser/vent suit heat exchanger and water extractor and simultaneously reheats the dried air before expansion through the turbine end of the refrigeration turbine/compressor assembly. The function of the reheater is to decrease the amount of cooling provided by the condenser heat exchanger and increase turbine inlet temperature, which results in increased turbine power.

Condenser/Vent Suit Heat Exchanger

The condenser/vent suit heat exchanger is a cross-flow, air-to-air heat exchanger, which uses cold turbine discharge air from the refrigeration turbine/compressor assembly to cool and condense moisture from the bleed air before circulation through the water extractor. The heat exchanger inlet receives partially cooled air from the hot side of the reheater and directs it across the condenser core where it is cooled until the water vapor is condensed into large size droplets. The air and water droplets are directed to the water extractor. A separate vent suit heat exchanger is in the condenser assembly. The vent suit heat exchanger receives dry air from the water extractor and cools it by heat exchange with turbine exhaust air for use in the vent suit system.

Water Extractor

The water extractor is an in-line, integral duct device that uses a helix and a water shave-off collector. Moisture-laden air from the condenser enters the water extractor and is given a swirling motion by the helix. The heavy water particles are centrifuged to the duct wall and shaved off into the annular section between the duct wall and reentrant discharge duct. Approximately 3 percent of the total airflow is also shaved off as scavenge air. The scavenge air/water enters the outer chamber, which is surrounded by a perforated muff. In this chamber the water droplets are separated from the scavenge air. The dry scavenge air flows into an end chamber, through a baffle and out through the scavenge port. The water flows through the perforations into a sump and out through the drain port to the water spray nozzle where it is used to augment ram air cooling in the secondary heat exchanger.

Refrigeration Turbine/ Compressor Assembly

The refrigeration turbine/compressor assembly is a centrifugal compressor with a turbine wheel mounted at each end of a common shaft. The compressor end receives partially conditioned air from the flow modulating system pressure regulator valve, where it is compressed to approximately double its inlet value. The air is transported through the secondary heat exchanger, reheater heat exchanger, condenser/vent suit heat exchanger, and water extractor before entering the turbine end of the refrigeration turbine/compressor assembly. The conditioned, dry air flows through turbine nozzles to the turbine wheel where heat energy is changed to mechanical energy, driving the compressor. The expanded, cold air exhausting from the turbine is transported back through the reheater heat exchanger, into ducting, where it is used for environmental control.

Anti-Ice Add Heat Valve

The anti-ice add heat valves is a normally closed, electrically controlled, pneumatically actuated, modulating valve. The valve is between the windshield anti-ice/rain removal manifold and the turbine outlet. The valve is controlled by electrical signals from the ACS temperature/flow controller and differential pressure sensed across the condenser/suit vent heat exchanger. This valve maintains the turbine outlet temperature as required to prevent icing by adding hot air to the conditioned, cold air.

SYSTEM TESTING

Air-conditioning test sets (testers) are used to test ACSs for proper operation and to troubleshoot system malfunctions. Some newer aircraft being introduced into the fleet have an aircraft installed tester. This built-in tester (BIT) performs many tests of the system in flight. The following is an example of the F-18 automatic test sequence.

The ACS BIT starts when electric power is applied to the ACS temperature/flow controller. In-flight BIT is a complete sequence of tests on the ACS temperature/flow controller and 10 electrically interfacing components. Nine seconds are required for a complete BIT sequence, and the BIT sequence is repeated every 90 seconds. If the same test indicates a failure on two consecutive BIT sequences, the BIT processor removes a ground from the signal data converter, and a maintenance code is recorded. After a maintenance code is recorded, BIT is inhibited until electrical power is removed and reapplied. When the aircraft is on the ground, BIT operation is the same as in-flight BIT except that only part of the BIT sequence is performed.

BIT tests the flow modulating system pressure regulator valve to produce the following indications:

BIT tests for OPEN CIRCUITS in the valve torque motor and position feedback transducer during any mode of operation, and will produce a failure signal if an open circuit is detected.

BIT tests for VALVE STUCK OPEN condition by comparing a high avionics airflow condition with a high torque motor current (closing signal to valve). When both of these indications exist, a failure signal is produced.

BIT tests for VALVE STUCK CLOSED when airflow to the cabin and avionics are low. The BIT failure signal is inhibited if the valve position transducer indicates the valve is full open.

COMMON AIR-CONDITIONING COMPONENTS

Some components and hardware are common to all ACSs. Bleed-air ducting is manufactured from stainless steel and can withstand pressures up to 450 psi and temperatures up to 800°F (425°C). These ducts are covered with high-temperature insulation (fig. 3-3) to protect aluminum structures and electrical lines near the ducting. Bellows assemblies are manufactured for two functions. The tolerance compensator (fig. 3-4) can be adjusted in length and allows for easier removal and replacement of the bleed-air duct. The thermal compensator (fig. 3-5) allows for thermal expansion throughout the bleed-air ducting. To support and brace the ducting, flexible mounting brackets are used (fig. 3-6). The use of these and other types of support brackets will vary with location and type of duct used. Air-conditioning distribution lines are manufactured from aluminum alloy and are subjected to relatively low pressures and temperatures.

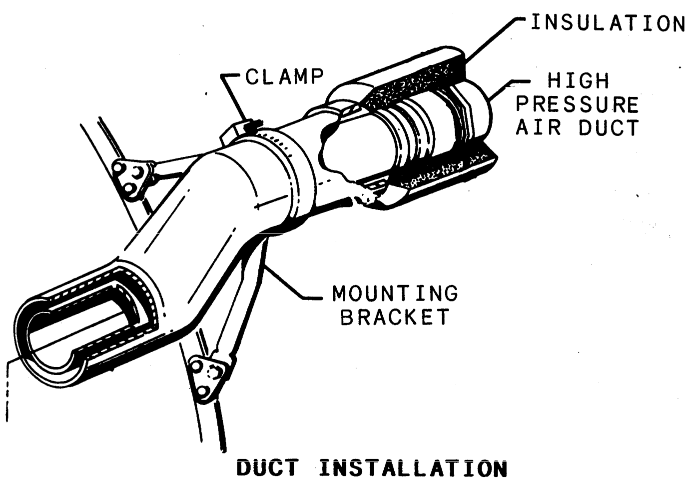
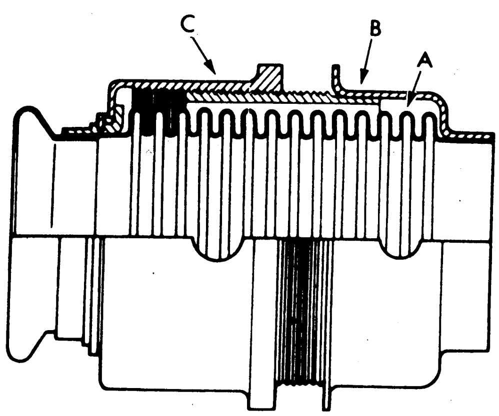
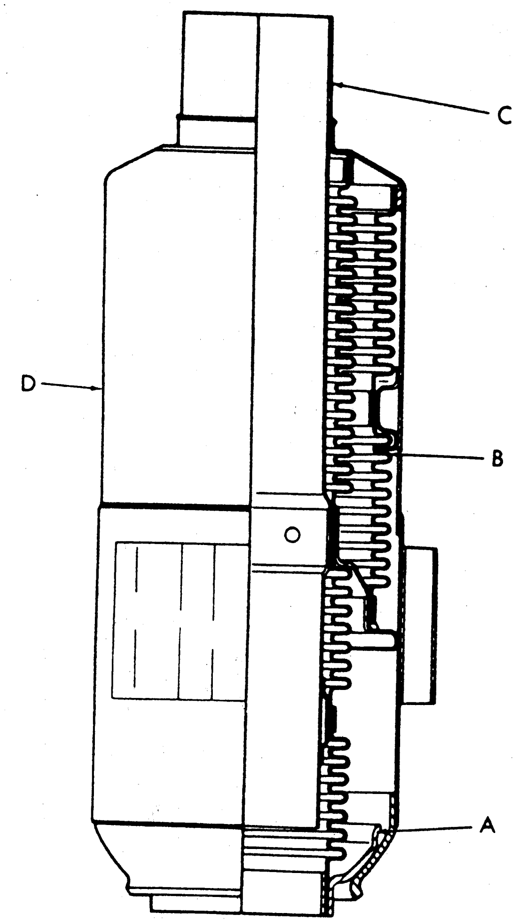


Figure 3-3.—Bleed-air ducting.



A. Bellows assembly
B. Adapter
C. Coupler

Figure 3-4.—Tolerance compensator.



A. Swivel joint
B. Bellows assembly
C. Inner tube
D. Outer chamber

Figure 3-5.—Thermal compensator.

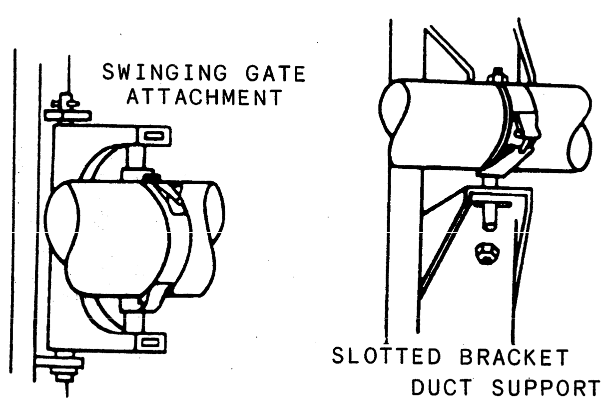


Figure 3-6.—Flexible mounting brackets.

A variety of clamping devices are used in connecting aircraft environmental control system ducting sections to each other or to various components. Whenever lines, components, or ducting are disconnected or removed for any reason, install plugs, caps, or coverings on the openings to prevent the entry of foreign materials. Tag the various parts to ensure correct reinstallation. Care should be exercised during handling and installation to ensure that flanges are not scratched, distorted, or deformed. Flange surfaces should be free of dirt, grease, and corrosion. The protective flange caps should be left on the ducting until the installation progresses to the point where removal is necessary to continue with the installation.

In most cases it is mandatory to discard and replace seals and gaskets. Ensure that seals and gaskets are properly seated and that mating and alignment of flanges are fitted so that excessive torque is not required to close the joint and impose structural loads on the clamping device. Adjacent support clamps and brackets should remain loose until installation of the coupling has been completed.

Marman type clamps commonly used in ducting systems should be tightened to the torque value indicated on the coupling. Tighten all couplings in the manner and to the torque value as specified on the clamp or in the applicable MIM.

Some of the most commonly used plain band couplings (flexible line connectors) are illustrated in figure 3-7. When installing a hose between two

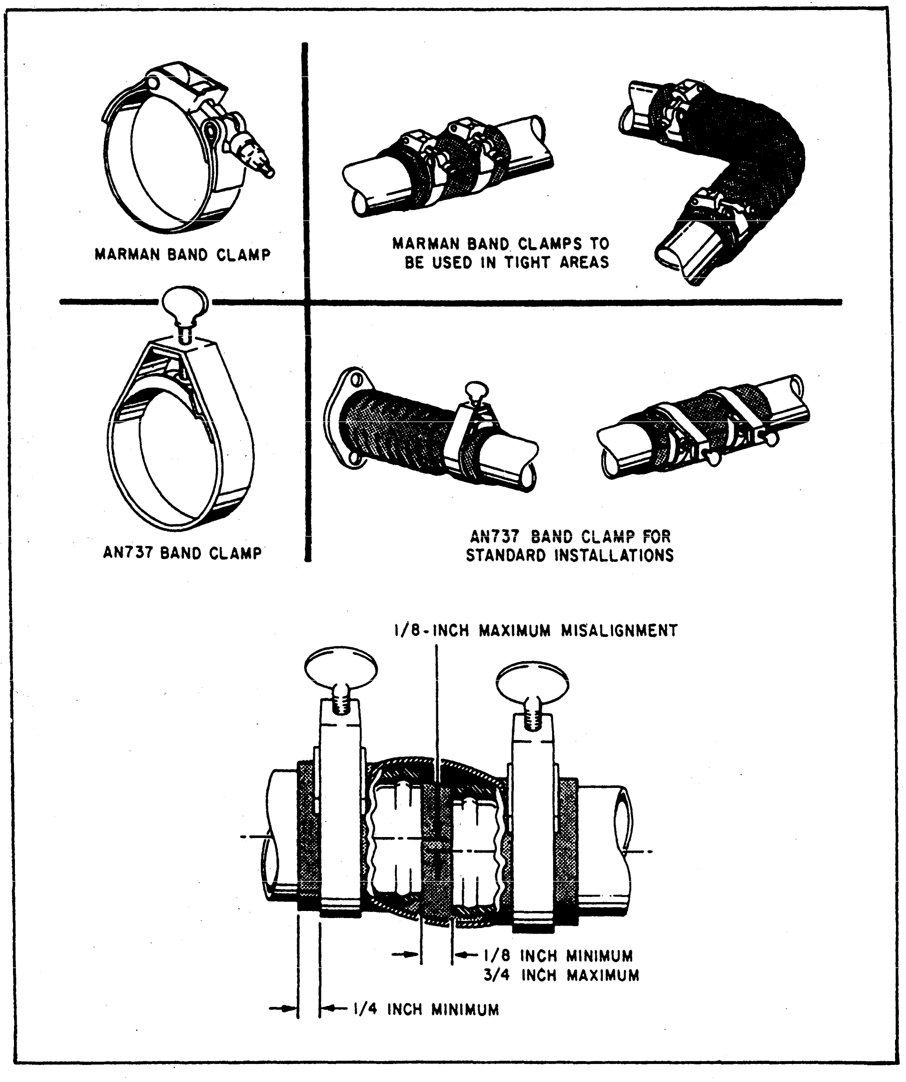


Figure 3-7.—Flexible line connectors.

duct sections, as illustrated in figure 3-7, the gap between the duct ends should be 1/8 inch minimum to 3/4 inch maximum. When installing the clamps on the connection, the clamp should be 1/4 inch minimum from the end of the connector. Misalignment between the ducting ends should not exceed 1/8 inch maximum.

When installing flexible line connectors, such as the one illustrated in figure 3-8, follow the steps listed below to assure proper installation and security:

1. Fold back half of the sleeve seal and slip it onto the sleeve.

2. Slide the sleeve (with the sleeve seal partially installed) onto the line.

3. Position the split sleeves over the line beads.

4. Slide the sleeve over the split sleeves and fold over the sleeve seal so that it covers the entire sleeve.

5. Install the coupling over the sleeve seal and torque to correct value.

NOTE: Torque values for the various sizes and types of couplings maybe found by referring to the applicable MIM. Some couplings will have the correct torque value marked on the outside of the band.

When installing rigid line couplings, follow the steps listed below and illustrated in figure 3-9:

1. Slip the V-band coupling over the flanged tube.

2. Place a gasket into one flange. One quick rotary motion assures positive seating of the gasket.

3. Hold the gasket in place with one hand while the mating flanged tube is assembled into the gasket with a series of vertical and horizontal motions to assure the seating of the mating flange to the gasket.

NOTE: View B of figure 3-9 illustrates the proper fitting and connecting of a rigid line coupling, using a metal gasket between the ducting flanges.

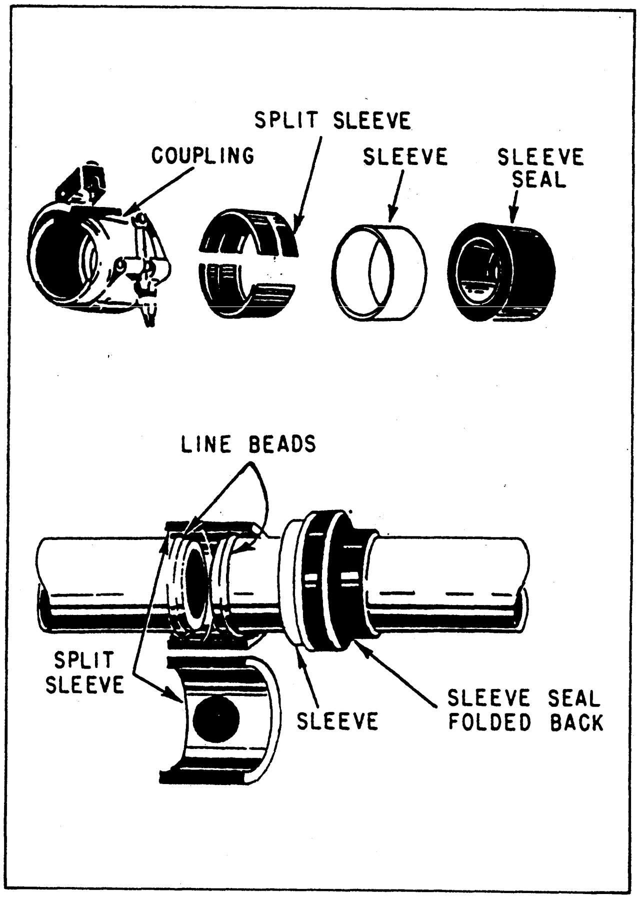


Figure 3-8.—Installation of flexible line connectors.

4. While holding the joint firmly with one hand, install the V-band coupling over the two flanges.

5. Press the coupling tightly around the flanges with one hand while engaging the latch.

6. Tighten the coupling firmly with a ratchet wrench. Tap the outer periphery of the coupling with a plastic mallet to assure proper alignment of the flanges in the coupling. This will seat the sealing edges of the flanges in the gasket. Tighten again, making sure the recommended torque is not exceeded.

7. Check the torque of the coupling with a torque wrench and tighten until the specified torque is obtained.

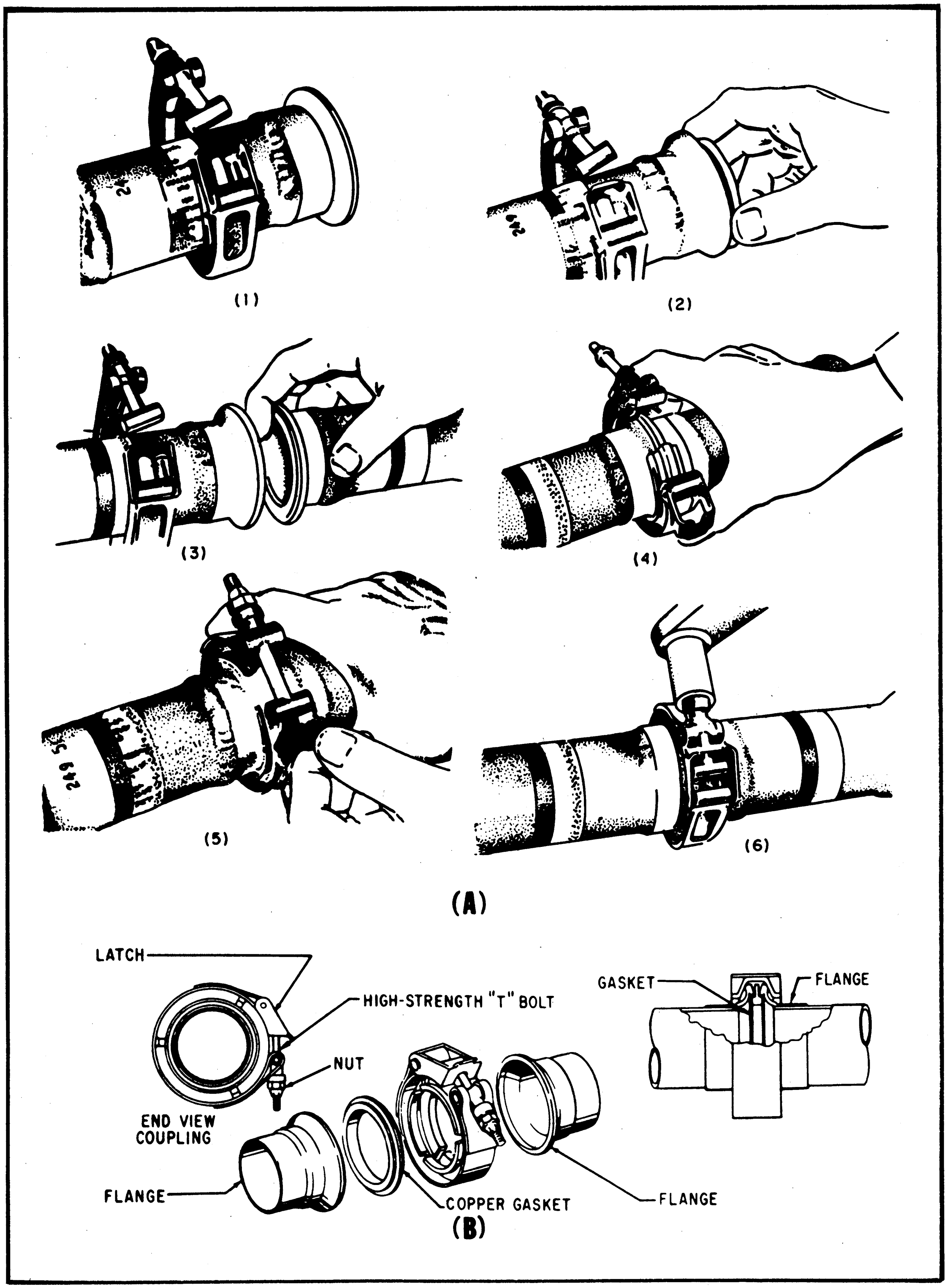


Figure 3-9.—Installation of rigid line couplings.

CABIN COOLING AND ANTIFOG SYSTEMS

Learning Objective: Recognize the components and functions of cabin cooling and antifog systems.

The F-18 aircraft cabin cooling and antifog system (fig. 3-10) controls and transports conditioned air to the cabin. Conditioned air from the air cycle ACS is transported to the cabin flow valve where cabin inlet airflow is controlled by signals from the cabin airflow/temperature sensor through the ACS temperature/flow controller. Air leaving the cabin flow valve is mixed with hot air from the cabin add heat valve through signals from the suit/cabin temperature control, cabin airflow/temperature sensor, and the ACS temperature/flow controller. The conditioned air is divided between cabin air and windshield defog air by the cabin defog plenum distribution valve through the control handle and linkage and push-pull control.

Cabin cooling and antifog components are discussed in the following paragraphs.

CABIN FLOW VALVE

The cabin flow valve is a normally open, electropneumatically controlled modulating valve. The valve responds to signals from the cabin airflow/temperature sensor and the ACS temperature/flow controller to maintain cabin inlet airflow at a differential pressure above cabin pressure. A control circuit in the ACS temperature/flow controller compares the signal from the cabin airflow/temperature sensor with a preset reference and produces the required signal to modulate the cabin flow valve to satisfy the flow requirements. A position indicator is visible on the valve body.

CABIN ADD HEAT VALVE

The cabin add heat valve is an electropneumatic, butterfly, modulating valve. The valve modulates hot airflow into the cabin inlet duct in response to electrical signals from the cabin airflow/temperature sensor through the ACS temperature/flow controller and suit/cabin temp control. As cabin inlet air temperature decreases to below the required level, as selected by the suit/cabin temp control, the cabin airflow/temperature sensor and ACS temperature/flow controller provide an electrical signal to the valve torque motor, allowing regulated air pressure to open the valve. When electrical current to the valve is below a minimum, the valve is held closed by spring pressure. If a cabin air supply overtemperature occurs, the cabin air overtemperature sensor vents control pressure from the valve, allowing it to close. A position indicator is visible on the valve body.

CABIN AIR OVERTEMPERATURE SENSOR

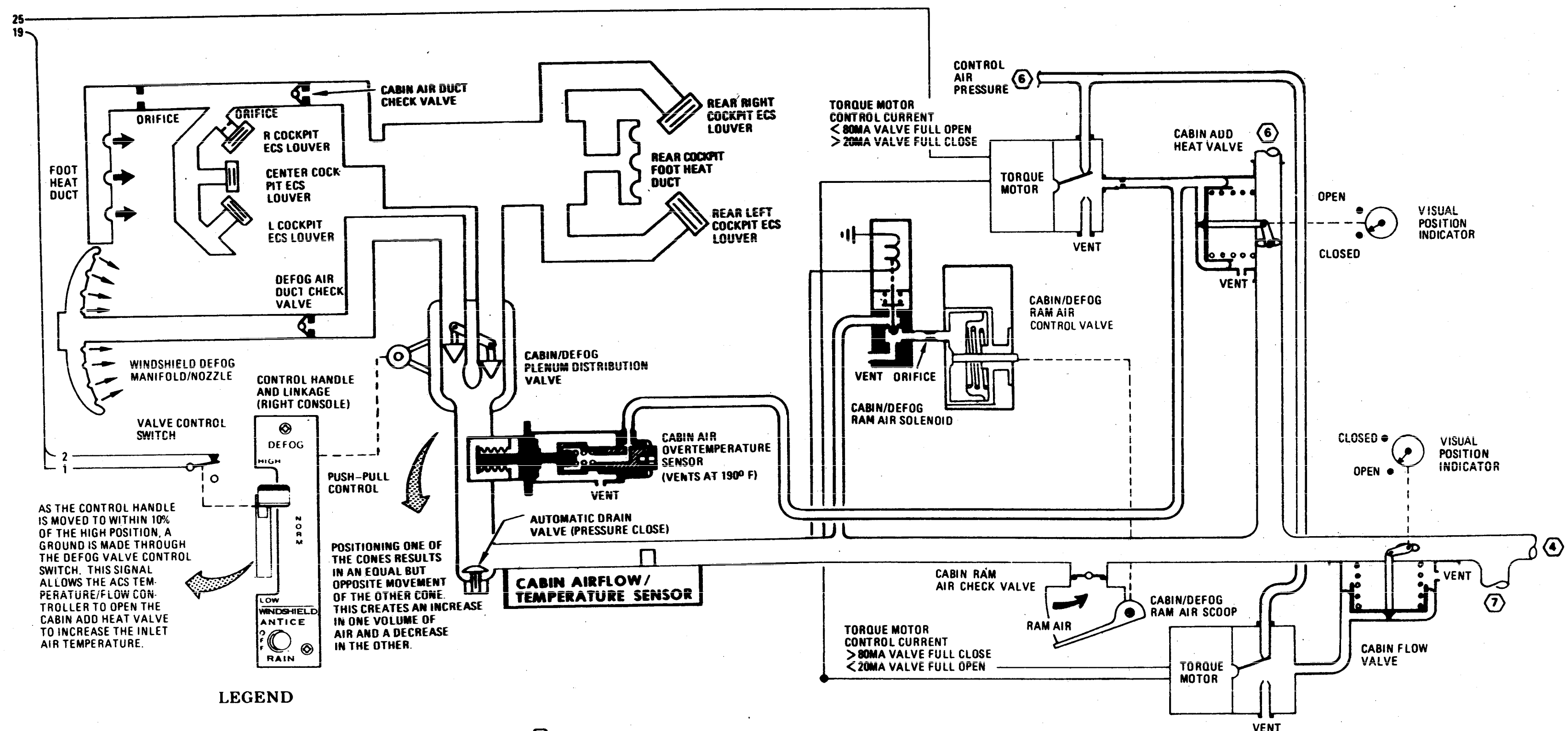
The cabin overtemperature sensor is a pneumatic bleedoff type. It is installed in the cabin distribution duct downstream of the cabin add heat valve. At a preset temperature, the expansion bellows unseats a ball. Control head pressure is vented overboard allowing the cabin add heat valve to close.

ECS RAM AIR ACTUATOR ASSEMBLY

The actuator part of the ram air system supplies mechanical force to extend the ram air scoop. The actuator is connected to the ram air scoop through linkage. It is held closed when air pressure is applied and the ECS ram air solenoid is de-energized. The actuator opens when there is a loss of air pressure or when the solenoid is energized.

ECS RAM AIR SOLENOID ASSEMBLY

The solenoid assembly is mounted in the duct upstream of the actuator for the ram air scoop.



LEGEND

1. ALL WIRE NUMBERS, SPLICE POINTS AND GROUND POINTS ARE SHOWN IN A1-F18A( )-WDM-000.

(2) SUIT VENTILATION SYSTEM SIMPLIFIED SCHEMATIC WP011 00.

(3) RADAR LIQUID COOLING SYSTEM SIMPLIFIED SCHEMATIC WP013 00.

(4) AIR CYCLE AIR CONDITIONING SYSTEM SIMPLIFIED SCHEMATIC WP005 00.

(5) CABIN PRESSURIZATION SYSTEM SIMPLIFIED SCHEMATIC F-18A WP003 00.

(6) WINDSHIELD ANTI-ICE AND RAIN REMOVAL SYSTEM SIMPLIFIED SCHEMATIC WP012 00.

(7) AVIONICS COOLING SYSTEM SIMPLIFIED SCHEMATIC - EXCEPT COCKPIT WP007 00.

(8) MAINTENANCE STATUS DISPLAY AND RECORDING SYSTEM, NON AVIONICS MAINTENANCE CODES SIMPLIFIED SCHEMATIC, A1-F18AA-580-100, WP003 00.

(9) AIR DATA COMPUTER SYSTEM SIMPLIFIED SCHEMATIC, A1-F18AA-560-100, WP003 00.

(10) LANDING GEAR CONTROLLED RELAYS SIMPLIFIED SCHEMATIC A1-F18AA-130-100, WP003 00.

(11) GROUND POWER SWITCHING SIMPLIFIED SCHEMATIC A1-F18AA-420-100, WP005 00.

(12) AIR CONDITIONING SYSTEM BIT STARTS WHEN ELECTRIC POWER IS APPLIED TO THE ACS TEMPERATURE/FLOW CONTROLLER. INFLIGHT BIT IS A COMPLETE SEQUENCE OF TESTS ON THE ACS TEMPERATURE/FLOW CONTROLLER AND TEN ELECTRICALLY INTERFACING COMPONENTS. NINE SECONDS IS REQUIRED FOR A COMPLETE BIT SEQUENCE, AND THE BIT SEQUENCE IS REPEATED EVERY 90 SECONDS. IF THE SAME TEST INDICATES A FAILURE ON TWO CONSECUTIVE BIT SEQUENCES, THE BIT PROCESSOR REMOVES A GROUND FROM SIGNAL DATA CONVERTER CV-3493/ASM-612, AND A MAINTENANCE CODE IS RECORDED. AFTER A MAINTENANCE CODE IS RECORDED, BIT IS INHIBITED UNTIL ELECTRICAL POWER IS REMOVED AND REAPPLIED. WHEN THE AIRCRAFT IS ON THE GROUND, BIT OPERATION IS THE SAME AS INFLIGHT BIT EXCEPT THAT ONLY A PARTIAL BIT SEQUENCE IS DONE.

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Figure 3-10.—Cabin cooling and antifog system.

The solenoid is electrically controlled, and when energized, it allows air pressure to be vented and the ram air scoop opens.

CABIN AIRFLOW/TEMPERATURE SENSOR

The cabin airflow/temperature sensor is a flow sensor and a temperature sensor in a single unit. The sensor is installed in the cabin air inlet duct and provides electrical signals to the ACS temperature/flow controller based on air temperature and flow. The electrical signals are used by the ACS temperature/flow controller for automatic operation of the cabin flow valve and cabin add heat valve.

AUTOMATIC DRAIN VALVE

The automatic drain valve, located in the cabin air supply duct, is open to drain moisture from the supply duct. The valve closes when air pressure is applied to the system.

CABIN DEFOG PLENUM DISTRIBUTION VALVE

The cabin defog plenum distribution valve, located in the cabin inlet duct, is a manually controlled valve that divides the flow of cabin inlet air between cabin cooling and windshield defog. The valve contains two movable, shaft-mounted cones that regulate airflow. Movement of one cone causes an equal and opposite movement of the other cone. This causes an increase in one volume of air and a decrease in the other. The valve is controlled by the cockpit-mounted control handle and linkage, through the push-pull control.

CONTROL HANDLE AND LINKAGE

The control handle and linkage allows the pilot to set the cabin defog plenum distribution valve to control the flow of windshield defog and cabin cooling air. An electrical limit switch is installed in the control handle housing. The switch is activated when the handle is within 10 percent of HIGH defog. When activated, the switch sends a signal to the ACS temperature/flow controller to increase the temperature of the defog air by opening the cabin add heat valve.

PUSH-PULL CONTROL

The push-pull control connects the control handle and linkage with the cabin defog plenum distribution valve. Movement of the control handle and linkage is transmitted to the cabin defog plenum distribution valve by the push-pull control.

SUIT/CABIN TEMPERATURE CONTROL

The suit/cabin temp control contains two dual section potentiometers. The potentiometers have an outer shaft and control knob for cabin temperature control and an inner shaft and control knob for vent suit temperature control. The cabin temperature control potentiometer provides electrical signals to the ACS temperature/flow controller for automatic temperature control and directly controls the position of the cabin add heat valve for manual temperature control.

AUTOMATIC TEMPERATURE CONTROL

Automatic temperature control is selected by setting the ECS mode switch to AUTO. In the auto mode, the pilot selects the cabin temperature by adjusting the cabin knob of the suit/cabin temp control. The ACS temperature/flow controller produces a reference signal in relation to the setting selected on the suit/cabin temp control. A control circuit in the ACS temperature/flow controller compares a signal from the temperature sensing element of the cabin airflow/temperature sensor with the reference signal and modulates a control signal to the cabin add heat valve to maintain the selected temperature.

MANUAL TEMPERATURE CONTROL

Manual temperature control is selected by setting the ECS mode switch to MAN. In the manual mode, adjusting the cabin knob of the suit/cabin temp control determines the control signal sent to the cabin add heat valve.

EQUIPMENT COOLING SYSTEMS

Learning Objective: Recognize the source for avionics cooling air; identify components of avionics cooling systems and the function of each component.

As electronics and avionics in naval aircraft became more common and more sophisticated, it was discovered that the heat generated by this equipment was becoming excessive for proper operation. A means of keeping the avionics at a proper operating temperature was needed. To overcome this problem, some aircraft have. separate ACS for equipment cooling, while others use conditioned air diverted from the environmental ACS.

If the equipment ACS is an air-to-air type, its operation is the same as the environmental ACS discussed at the beginning of this chapter. Only operating temperatures will be different. The other type of equipment air conditioning (vapor cycle) operates on the same principal as a home ACS and will be discussed later in this chapter.

AIR-TO-AIR SYSTEM

The F-18 aircraft avionics cooling system (fig. 3-11, a foldout at the end of this chapter) controls and transports conditioned air to the various avionics packages and equipment bays. Conditioned air from the air cycle ACS is transported to the avionics flow valve where inlet pressure and airflow is controlled in response to signals from the avionics flow/temperature sensor through the ACS temperature/flow controller. Airflow rates are matched to the individual cooling requirements of each equipment package or bay.

Ground cooling of the avionics equipment bays is provided by an avionics ground cooling fan. The cockpits avionics equipment cooling is done by four cockpit avionics cooling fans, two in the forward cockpit and two in the rear cockpit.

Emergency ram air cooling for essential avionics equipment is provided by an emergency ram air scoop and avionics ram air valve.

The avionics cooling components are discussed in the following paragraphs.

Avionics Airflow Valve

The avionics airflow valve is a normally open, pneumatically actuated and controlled pressure regulating valve. The valve is in the avionics supply line and maintains a pressure differential of 1.5 psi between an externally sensed upstream duct pressure and an externally sensed cabin duct pressure. Actuator spring pressure holds the valve butterfly to full open. Cabin pressure is sensed on one side of the control diaphragm and upstream valve pressure is sensed on the other side. If no pressure is applied to the control diaphragm, the feedback spring holds the control nozzle closed. Any external supply pressure applied under this condition overrides the actuator spring pressure and closes the valve.

Avionics Flow/Temperature Sensor

The avionics flow/temperature sensor is made up of a flow sensor and temperature sensor enclosed in a single unit. The sensor is in the supply line downstream of the avionics airflow valve. The sensor provides signals to the flow sensing and anti-ice temperature sensing bridges in the ACS temperature/flow controller for automatic operation of the flow modulating system pressure regulator valve and anti-ice add heat valve.

Avionics Ram Air Valve

The avionics ram air valve is a normally open, pneumatically closed, remote-controlled shutoff valve. It is between the secondary heat exchanger ram air inlet and the avionics supply line. The valve provides ram air augmentation for avionics cooling if cooling airflow drops below an established limit. The valve is closed by pneumatic pressure and is opened by pneumatic signals from a remotely located avionics ram air servo. Pressure is supplied from the servo to hold the valve closed. When externally supplied pressure from the servo drops below a specified value, the valve opens and supplies ram air.

ECM Cooling Air Control Valve

The ECM cooling air control valve is a two-position solenoid controlled valve. The valve provides a high flow of cooling air to the electronic countermeasure (ECM) package when de-energized and a low flow when energized. The valve is energized when the ECM mode switch on the ECM control panel assembly is selected to OFF or STBY.

Avionics Ground Cooling Fan

The avionics ground cooling fan is an electrically driven axial flow fan that provides a flow of ambient air for direct avionics cooling during aircraft ground operation, taxi, takeoff, and landing. The fan is in the nose wheelwell and is powered by an induction motor.

Avionics Ground Cooling Fan Check Valve

The avionics ground cooling fan check valve is made up of two spring-loaded flappers hinged around a central shaft. The check valve is located between the upper and lower plenums, and it functions to prevent cooling air from escaping through the avionics ground cooling fan during flight.

Avionics Fan Control Pressure Switch

The avionics fan control pressure switch is a pneumatically operated switch in the ducting downstream of the primary heat exchanger. This switch controls the avionics ground cooling fan operation to provide supplemental air for avionics equipment cooling.

Emergency Ram Air Scoop

The emergency ram air scoop is a spring-loaded scoop on the forward fuselage. The scoop is held closed by a solenoid, which releases the scoop when energized. A linkage arrangement, connected to the scoop, closes a flapper on the avionics cooling plenum and directs ram air to the essential avionics when the scoop is opened. The FCS cool switch, on the right vertical console, activates the scoop release solenoid when set to EMERG.

Avionics Undercool Warning Temperature Sensor

The avionics undercool/warning temperature sensor is made up of two temperature sensing elements, one is self-heated. On detecting an undercool condition of avionics cooling air, the sensor sends a signal to the signal data converter, which displays the AV AIR HOT caution message on the left digital display indicator.

Avionics Cooling Fans

The two avionics cooling fans in the cockpit are axial flow fans driven by electric motors. Both fans operate continuously with any ground power switch to A ON or B ON or flt cent switch to ON. Individual cockpit fan operation can be verified by setting the fan test switch on the fan test control panel assembly to A LEFT or B RIGHT.

Rear Cockpit Avionics Cooling Fans

The rear cockpit avionics cooling fans are identical in design and function to the cockpit avionics cooling fans. Individual rear cockpit fan operation can be verified by setting the fan test switch on the fan test control and utility light panel assembly to A LEFT or B RIGHT.

VAPOR CYCLE AIR-CONDITIONING SYSTEM

Vapor cycle systems make use of the scientific fact that a liquid can be vaporized at any temperature by changing the pressure above it. Water at sea level barometric pressure of 14.7 psi will boil at 212°F. The same water in a closed tank under a pressure of 90 psi will not boil at less than 320°F. If the pressure is reduced to 0.95 psi by a vacuum pump, the water would boil at 100°F. If the pressure is reduced further, the water would boil at a still lower temperature; for instance, at 0.12 psi, water will boil at 40°F. Water can be made to boil at any temperature if the pressure corresponding to the desired boiling temperature can be maintained.

Liquids that boil at low temperatures are the most desirable for use as refrigerants. Comparatively large quantities of heat are absorbed when liquids are evaporated; that is, changed to a vapor. For this reason, liquid Freon 12 or 22 is used in most vapor cycle refrigeration units whether used in aircraft or in home air conditioners and refrigerators.

If liquid Freon 12 were poured into an open container surrounded by standard sea level pressure, it would immediately begin to boil at temperatures above -22°F (-30°C). There would be a continuous flow of heat from the warm surrounding air through the walls of the container to the boiling Freon. Moisture from the air would condense and freeze on the exterior of the container.

This open container system would work satisfactorily insofar as cooling alone is concerned. A drum of Freon could be connected to a coil and the vaporized Freon piped outdoors. A system such as this would provide satisfactory refrigeration, but the cost of continuously replacing the refrigerant would be prohibitive. Because of the cost involved, it is desirable to use the refrigerant over and over. To accomplish this, additional equipment, over and above that already mentioned, is required.

Vapor Cycle Theory

Refrigerant used in the vapor cycle refrigeration system occurs as both a liquid and as a vapor. Conversion from a liquid to a vapor will occur at temperatures above – 21°F (– 34°C) at sea level. If the refrigerant pressure is increased, conversion to a vapor will occur at higher temperatures. Maximum heat transfer efficiency occurs when the refrigerant is at the boiling point (the point at which the liquid will vaporize).

The refrigerant must be delivered to the evaporator as a liquid if it is to absorb large quantities of heat. Since it leaves the evaporator in the form of a vapor, some way of condensing the vapor is necessary. To condense the refrigerant vapor, the heat surrendered by the vapor during condensation must be transferred to some other medium. For this purpose, water or air is ordinarily used. The water or air must be at a temperature lower than the condensing temperature of the refrigerant. At any given pressure, the condensing and vaporizing temperature of a fluid are the same. If a refrigerant that vaporizes at 40°F (5°C) is to be condensed at the same temperature, water or air at a lower temperature is needed. Obviously, if water or air at this lower temperature were available, mechanical refrigeration would not be required. As the temperature of available water or air is usually always higher than the temperature of the boiling refrigerant in the evaporator, the refrigerant must be condensed after it leaves the evaporator. To condense the vapor, its pressure must be increased to a point that its condensing temperature will be above the temperature of the water or air available for condensing purposes. For this purpose a compressor is needed. After the pressure of the refrigerant vapor has been increased sufficiently, it may be liquefied in the condenser with comparatively warm water or air.

In a practical refrigeration circuit, liquid flows from the receiver to the expansion valve, which is essentially nothing more than a needle valve. The compressor maintains a difference in pressure between the evaporator and the condenser. Without the expansion valve, this difference in pressure could not be maintained. The expansion valve separates the high-pressure part of the system from the low-pressure part. It acts as a pressure reducing valve because the pressure of the liquid flowing through it is lowered. Only a small trickle of refrigerant fluid flows through the valve into the evaporator. The valve is always adjusted so that only the amount of liquid that can be vaporized in the evaporator passes through it.

The liquid that flows through the evaporator is entirely vaporized by the heat flowing through the walls of the evaporator. This heat has been removed from the air being cooled.

After leaving the evaporator, the vaporized refrigerant flows to the compressor where its pressure is raised to a point where it can be condensed by the condenser airflow available. After being compressed, the vapor flows to the condenser. Here, the walls of the condenser are cooled by the water or air; and as a result, the vapor is liquefied. Heat is transferred from the condensing vapor to the water or air through the walls of the condenser. From the condenser the liquid refrigerant flows back to the receiver, and the cycle is then repeated.

Operations and Components

The Grumman Aerospace Corporation chose a Freon 12 vapor cycle ACS to provide avionics equipment cooling in the E-2 “Hawkeye” aircraft. This system, the VEA6-1, is described in this section. The basic difference between the basic vapor cycle system and the VEA6-1 system is the method of compensating for the variations in ram air temperature and the variation in the flow of ram air, which is dependent on aircraft speed. Figure 3-12 is a schematic diagram of the VEA6-1 vapor cycle ACS.

In the E-2 configuration, the vapor cycle system cools, filters, and distributes avionics compartment air at a temperature of 38°±5°F.

The system consists of a vapor cycle cooling scoop assembly, an evaporator group assembly, and air distribution ducting interconnected by refrigerant lines and electrical wiring.

The evaporator assembly (fig. 3-13) is a compact, quick-change package that can be easily installed, removed, and serviced as a unit. The assembly is composed of five quick-disconnect couplings; two shock mounts; temperature controls; a hydraulic, motor-driven, self-lubricating Freon compressor; a receiver; a subcooler; a thermostatic expansion valve; an evaporator; hydraulic motor-driven fan; and an oil separator.

The vapor cycle cooling scoop assembly is mounted on the top of the fuselage and consists of a condenser assembly, ejector nozzles, an actuator and flap, and a refrigerant pressure actuator control switch.

The Freon 12 in the closed system is the primary coolant. The forced air that is drawn through the evaporator in a continuous cycle is the secondary coolant. The electronic equipment is cooled by the secondary coolant, which removes heat by direct contact with the equipment to be

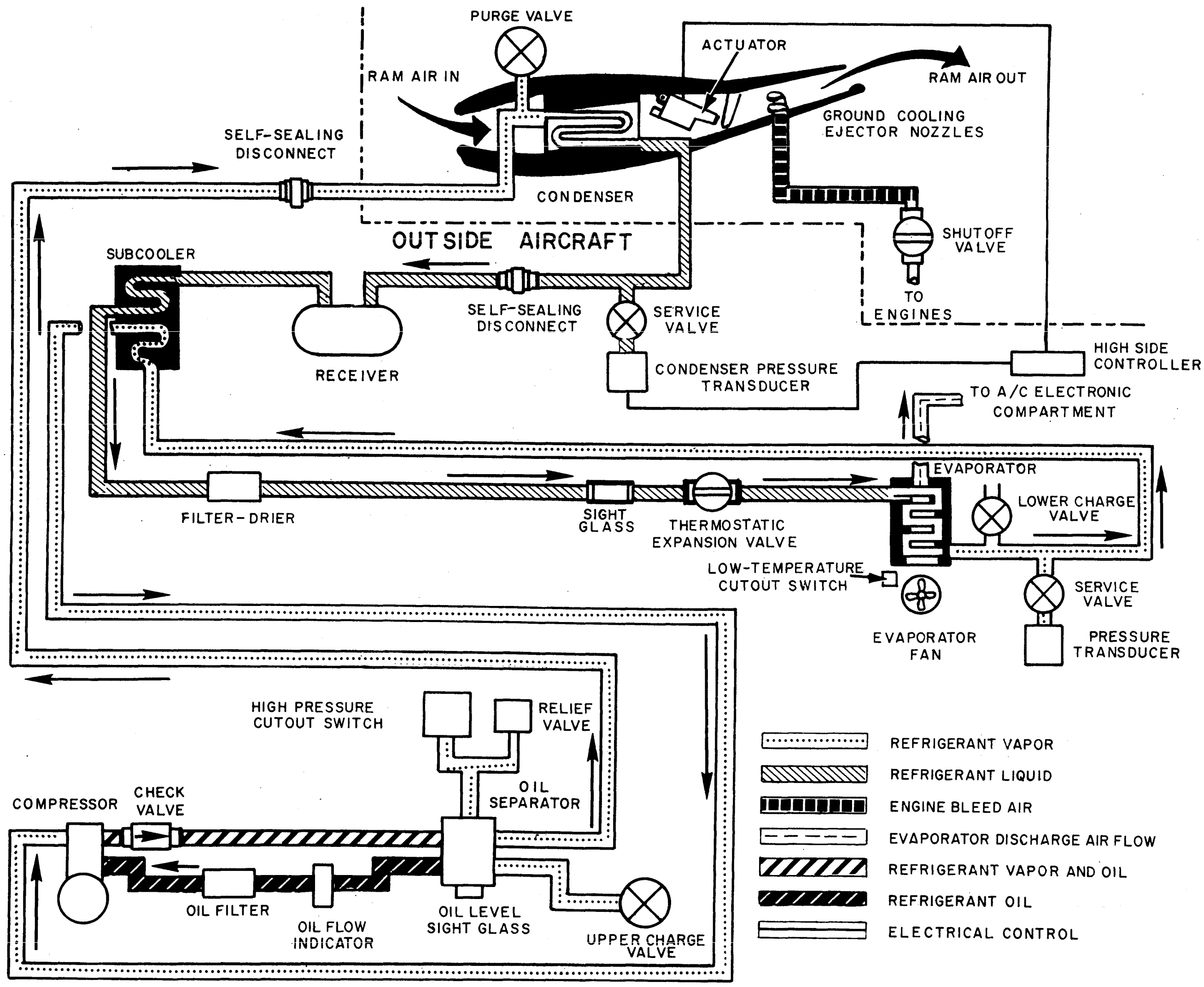

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Figure 3-12.—Vapor cycle air-conditioning system.

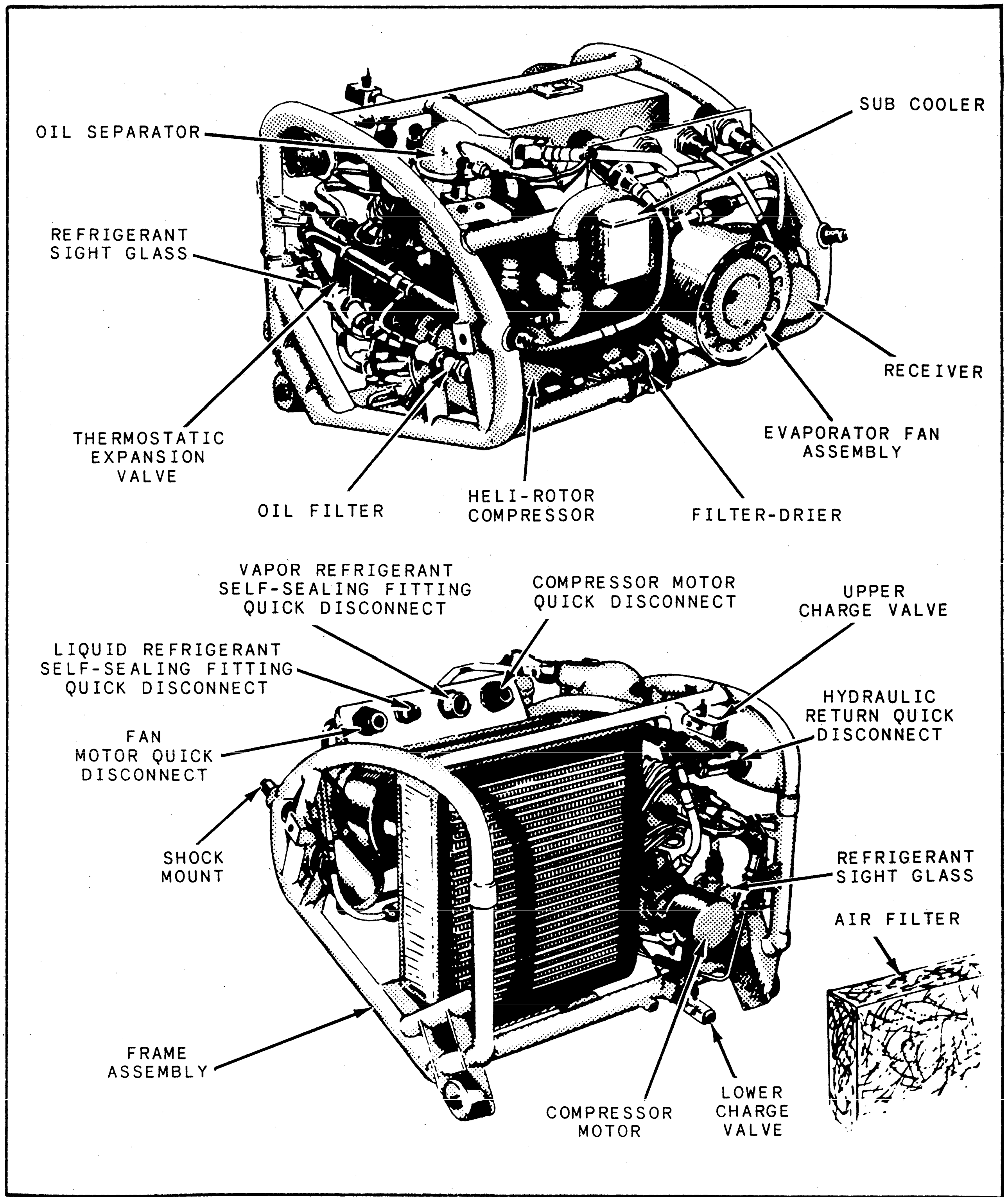

Figure 3-13.—Evaporator assembly.

cooled and the transfer of this heat to the primary coolant through the evaporator assembly.

A header assembly attached to the discharge side of the evaporator assembly directs the secondary coolant air to distribution ducts throughout the electronic equipment compartment. A filter between the header assembly and the evaporator assembly removes dirt and dust particles and traps moisture from the air.

The closed system consists of the evaporator group assembly and the condenser group assembly. The coolant circulates between the evaporator group assembly (where it absorbs heat) and the condenser group assembly where it discharges or dissipates the heat to the atmosphere through the vapor cycle scoop.

During flight, ram air flowing through the scoop cools the condenser group assembly. The airflow through the scoop is controlled by a condenser pressure control system. The actuator in the scoop modulates the airflow through the scoop to provide sufficient cooling for condensation of the refrigerant.

When the aircraft is on the ground with engines running and ram airflow is insufficient for cooling, a condenser ejector air shutoff valve opens to permit engine bleed air to discharge through the ejector assembly. The ejector consists of a set of tubes that permit bleed air to escape into the ram air duct behind the condenser. The escaping bleed air creates a negative pressure (suction) area behind the condenser and causes ambient air to be drawn into the scoop and across the condenser.

If the heat load applied to the evaporator and the ram air temperature and flow were constant, a simple opening would be all that was required to control the boiling point of the refrigerant entering the evaporator. Since these three factors are not constant, they must be compensated for. In the model VEA6-1 system, if the heat load is changed, the flow of refrigerant is changed by using a thermostatic expansion valve in place of a fixed opening. The pressure of the refrigerant in the evaporator is maintained constant, regardless of the refrigerant flow, by varying the speed of the compressor.

When the EQUIPMENT COOLING switch is set to ON, solenoid-operated shutoff valves are energized and hydraulic pressure is directed to the evaporator fan motor and the compressor motor. The compressor motor will be automatically shut off when either aircraft engine is in autofeather and the landing gear is down. The evaporator fan motor will continue to operate.

With the evaporator fan and compressor motors operating, low-pressure, low-temperature refrigerant Freon 12 vapor enters the compressor assembly through the low-pressure line leading from the evaporator assembly outlet. The vapor entering the compressor inlet combines with lubricating oil that is fed to the compressor. The oil-refrigerant mixture is compressed to raise its condensing temperature. From the compressor, the high-temperature, high-pressure mixture flows to the oil separator, where the oil is removed from the refrigerant vapor, filtered, and fed back to the compressor.

If the refrigerant vapor pressure exceeds 250 ± 5 psi in the line downstream from the oil separator, the high-pressure cutoff switch will cause the cockpit EQUIP COOLING caution light to illuminate and the compressor motor solenoid valve to shut off hydraulic pressure to the compressor motor, thus shutting down the compressor. If the cutout switch failed to operate properly, the relief valve in the compressor discharge line would relieve the system of pressure in excess of 325 psi.

Refrigerant vapor from the oil separator next enters the condenser assembly where ram air lowers its temperature and changes the vapor to a liquid. Refrigerant pressure on the high side of the system is controlled by regulating the amount of cooling air flowing across the condenser. A pressure transducer in the high side refrigerant line provides a signal to a control amplifier, which, in turn, causes the control actuator and flap to open and close as necessary to regulate pressure. The system is calibrated so that the condenser flap is fully closed when high side pressure is 107± 3 psi; fully opened at 151 ± 3 psi condensing pressure; and modulates the flap travel for intermediate pressures within that range.

If the cooling air is inadequate to maintain the pressure at 151 ± 3 psi with the flap fully open, the system pressure will exceed the control range. When the pressure reaches 250 ± 5 psi, the high--pressure cutout switch will shut down the vapor cycle system.

From the condenser assembly, liquid Freon flows to the receiver in the evaporator group assembly. The receiver stores surplus refrigerant and thereby prevents surges in the refrigerant flow rate. Liquid refrigerant flowing from the receiver passes through a subcooler and then through a filter drier, where foreign matter and water are removed. Before entering the thermostatic expansion valve, the liquid refrigerant passes through a sight glass, which provides a visual indication of flow and proper refrigerant charge. The refrigerant is metered by the thermostatic expansion valve, and then enters the evaporator assembly. The hydraulic motor-driven evaporator fan forces warm electronic equipment compartment air through the evaporator assembly, where it is cooled by transfer of heat to the refrigerant. The refrigerant leaves the evaporator as a superheated vapor.

The temperature of evaporator discharge air to the equipment compartment is controlled by controlling the speed of the compressor motor. The evaporator pressure control system maintains the refrigerant pressure within a specified range so that the average temperature range of the refrigerant is between 29.8° and 32.9° ± 0.6°F. This temperature range consequently controls air temperature to approximately 38°. The difference between the air and refrigerant temperatures is due to the efficiency of the heat exchanger.

If the equipment compartment temperature increases, refrigerant pressure on the low side will also increase. The increase in pressure is sensed by a pressure transducer located in the compressor inlet line, and a signal is sent to the evaporator pressure control system amplifier. The amplifier, in turn, sends an appropriate signal to the servo portion of the compressor hydraulic motor calling for a speed increase to prevent pressure increase and thus maintain a constant refrigerant pressure. If the temperature increase calls for a compressor motor speed above a maximum of 12,000 rpm, the temperature rise cannot be compensated for and the refrigerant pressure will rise. At 250 ± 5 psi compressor discharge pressure, the high side cutout switch will shut the vapor cycle system down.

If the equipment compartment temperature drops, a reverse situation exists. Compressor motor speed will decrease to a minimum of 4,000 rpm. If the temperature at the fan inlet continues to drop beyond the range that can be compensated (30°F), the low-temperature cutoff switch de-energizes the compressor power relay and shuts down the compressor motor. The refrigerant stops flowing while the evaporator fan motor continues to circulate compartment air. When the fan inlet temperature rises to 40° ± 2°F, the compressor is cut in and refrigerant flows through the evaporator and the subcooler and returns to the compressor to repeat the cycle.

The purpose of each major component in the vapor cycle system is discussed in the following paragraphs.

SUBCOOLER.— The subcooler (fig. 3-14) is a heat exchanger containing passages for liquid Freon 12 from the receiver on its way to the evaporator and cold Freon gas leaving the evaporator on its way to the compressor.

The purpose of the subcooler is to increase the efficiency of the system by cooling the refrigerant after it leaves the receiver, thereby preventing premature vaporization or flash off after passage through the expansion valve and before it reaches the evaporator. As stated previously, the refrigeration effect takes place when the Freon changes state from liquid to gas. Premature flash off would result in keeping additional refrigerant from evaporating and would have no useful effect on the primary cooling load required of the package.

The liquid on the way to the thermostatic expansion valve is relatively warm in comparison to the cold gas leaving the evaporator. Although the gas leaving the evaporator has absorbed heat from the air being circulated through the evaporator, its temperature is still in the vicinity of 40°F. This cool gas is fed through the subcooler where it picks up additional heat from the relatively warm liquid Freon 12 that is flowing from the receiver. This heat exchange causes the liquid to be subcooled to a level that ensures little or no flash gas on its way to the evaporator.

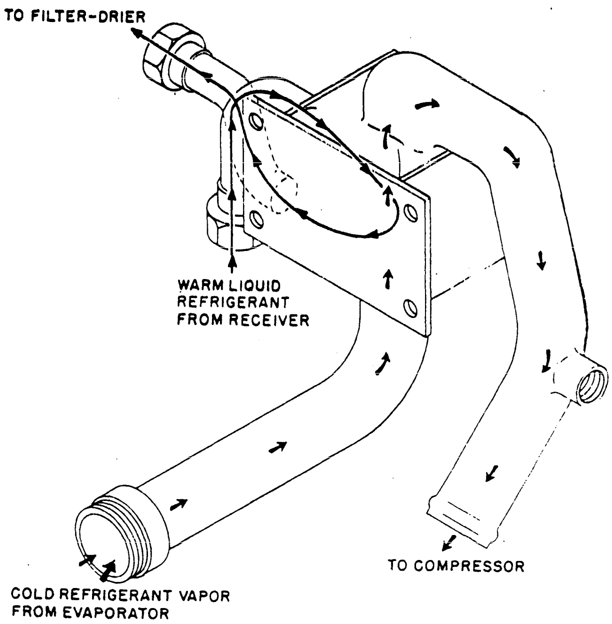

Figure 3-14.—Subcooler.

RECEIVER.— The receiver acts as a reservoir for the liquid Freon 12 refrigerant. The fluid level in the receiver varies with system demands. During peak cooling periods, there will be less liquid than when the load is light. The purpose of the receiver is to ensure that the thermostatic expansion valve is not starved for refrigerant under heavy cooling load conditions.

FILTER DRIER.— A filter drier unit (fig. 3-15) is installed in the plumbing between the sub-cooler and the sight glass. The unit is essentially a sheet metal housing with inlet and outlet connections and containing alumina desiccant, a filter screen, and a filter pad. Its purpose is to filter all contaminants and dry any moisture that may be present in the Freon 12 on its way to the expansion valve. The alumina desiccant acts as a moisture absorbent medium. The conical screen and fiber glass pad act as filtering devices, removing contaminants.

Clean refrigerant at the expansion valve is necessary because of the critical clearances involved. Moisture may freeze at the expansion valve, causing it to hang up with a resulting starvation or flooding of the evaporator.

The filter-drier unit is a "throwaway type" and is replaced whenever the charge is dumped from the unit or when filter-drier operation is doubtful.

SIGHT GAUGE.— To aid in determining whether servicing of the refrigerating unit is required, a sight gauge is installed in the line between the filter-drier and the thermostatic expansion valve. The gauge assembly consists of a fitting having windows on both sides, permitting a view of fluid passing through the line.

During refrigeration unit operation, if a steady flow of Freon refrigerant is observed through the sight glass, this is an indication that a sufficient charge is present. If the unit requires additional refrigerant, an indication will be the presence of bubbles in the sight glass. Since Freon is a colorless gas or liquid, a red-colored dye may be added to the liquid to facilitate leak detection. This is usually accomplished upon initial charging of the system.

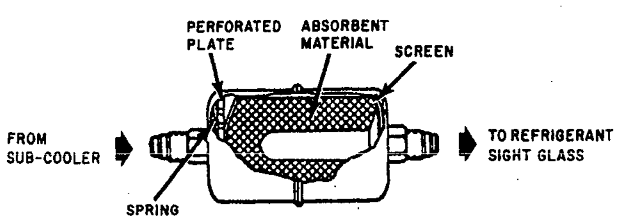

Figure 3-15.-Filter drier.

THERMOSTATIC EXPANSION VALVE.— The thermostatic expansion valve (fig. 3-16) is mounted close to the evaporator and meters the flow of refrigerant into the evaporator, depending upon system demand. Efficient evaporator operation is dependent upon the precise metering of liquid refrigerant into the heat exchanger for evaporation. As was previuosly stated, if heat loads on the evaporator were constant, a fixed opening size could be calculated and used to regulate the refrigerant supply. However, since the system encounters varying heat loads, a variable opening device is needed to prevent starvation or flooding of the evaporator, which would seriously affect the evaporator and system efficiency. This variable opening effect is accomplished by the thermostatic expansion valve, which senses evaporator conditions and meters refrigerant to satisfy them. By sensing the temperature and the pressure of the gas leaving the evaporator, the expansion valve prevents the evaporator from being flooded, and thereby returning liquid refrigerant to the compressor.

The valve consists of a housing containing an inlet port, an equalizer port, and 25 outlet ports. The flow of refrigerant to the outlet ports is controlled by positioning a metering valve pin. Valve pin positioning is controlled by the pressure created by the remote sensing bulb in the power section, the superheat spring setting, and the evaporator discharge pressure as supplied by the external equalizer port.

The remote sensing bulb is a closed system and is filled with refrigerant. The bulb itself is placed in a well, attached to the evaporator. The pressure within the bulb corresponds to the pressure of the refrigerant leaving the evaporator. This force is felt on top of the diaphragm in the power head section of the valve, and any increase in pressure will cause the valve to move towards an open position. The bottom side of the diaphragm has the forces of the superheat spring and the external equalizer port pressure acting in a direction to close the valve pin. The valve position at any instant is determined by the resultant of these three forces.

If the temperature of the gas leaving the evaporator increases above the desired superheat value, it will be sensed by the remote bulb. The

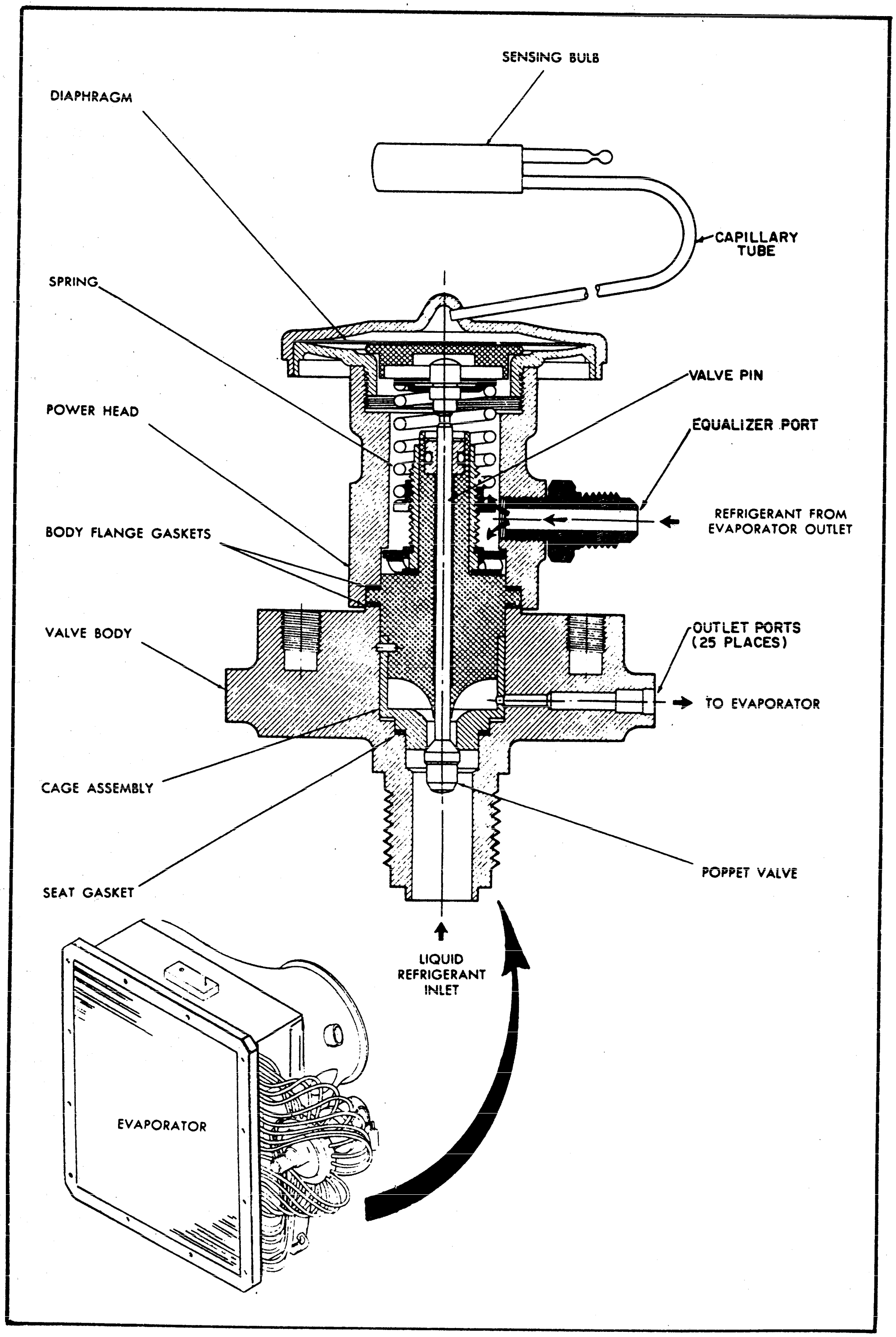

Figure 3-16.—Evaporator and thermostatic expansion valve.

pressure generated in the bulb is transmitted to the diaphragm in the power section of the valve, causing the valve pinto open. A decrease in the temperature of the gas leaving the evaporator will cause the pressure in the remote bulb to decrease, and the valve pin will move toward the closed position.

The superheat spring is designed to control the amount of superheat in the gas leaving the evaporator. A vapor is superheated when its temperature is higher than that necessary to change it from a liquid to a gas at a certain pressure. This ensures that the Freon returning to the compressor is in the gaseous state. The superheat spring is adjustable and is factory set to provide approximately 9° of superheat in this particular vapor cycle system. Superheat setting is calculated in relation to evaporator size and heat loads applied; therefore, it should never be tampered with in the field as serious inefficiencies will result.

The equalizer port is provided to compensate for the effect the inherent evaporator pressure drop has on the superheat setting. The equalizer senses evaporator discharge pressure and reflects it back to the power head diaphragm, adjusting the expansion valve pin position to hold the desired superheat value.

The purpose of the multioutlet configuration of the valve is to ensure an even distribution of the refrigerant in the evaporator.

EVAPORATOR.— The evaporator (fig. 3-16) is a plate fin heat exchanger forming passages for cooling airflow and for Freon 12 refrigerant. The evaporator assembly houses a hydraulically driven fan and a low-temperature cutout switch.

When the vapor cycle system is operating, refrigerant from the expansion valve flows into the Freon passages of the evaporator. At the same time, the hydraulically driven fan is forcing air from the electronic equipment compartment across the coils of the evaporator. The temperature of the air is rather high since it is affected by being circulated through the electronic boxes. This air, in passing through the evaporator, readily gives up its heat to the liquid Freon 12. The Freon is receptive to the heat exchange and, in absorbing the heat, a change of state comes about, changing the Freon from a liquid to a gas at approximately the same temperature that it was changed from a gas to a liquid. Since the Freon compressor is maintaining a constant pressure in the evaporator, the Freon vaporizes at a temperature that causes the air discharging from the evaporator to the electronic compartment to be at approximately 40°F. Vapor leaving the evaporator is also at a temperature of about 40°F.

Attached to the discharge side of the evaporator is a header duct assembly, bolted to the perimeter of the evaporator. This header is used to direct the discharged cooling air to the various distribution ducts. A set of movable louvers in the header is designed to act as a shutoff valve during ground cooling cart operations. During this time an external cart is attached to a receptacle on the right-hand side of the fuselage and feeds to the distribution system for ground operations, if desired. This air, however, would also escape in reverse direction through the evaporator and discharge into the forward compartment, thereby reducing the airflow to the electronic equipment. The louvers are actuated by a single control knob located at the top of the header duct. The knob is a two-position control (open and close) and is placarded to explain operation. To prevent the louvers from being inadvertently left in the closed position with the possibility of starving the avionics gear of cooling air after ground cart operation has been terminated, an overcenter device is incorporated. This device will automatically open the louvers as soon as a pressure is felt on them from the evaporator fan. The header duct also contains a discharge air filter, which filters the recirculated air and also removes the majority of the moisture (if present) in the cooling air on its way to the electronic equipment.

COMPRESSOR ASSEMBLY.— The purpose of the compressor assembly (fig. 3-17) is to evacuate the evaporator, keeping it at a constant pressure, and also to superheat the Freon vapor and feed it to the condenser where it is condensed back into a liquid for reuse. The compressor houses two intermeshing helical rotors that rotate in counterrotating directions. This action causes cool Freon gas to be taken from the evaporator and compressed. This increases its temperature and pressure to a value where it may be fed to the condenser for ambient air to change it back into a liquid. The compressor controls the pressure in the evaporator by varying its speed in response to signals from a suction line pressure switch.

The two intermeshing helical screw-type rotors are enclosed in a close tolerance housing, containing an inlet and an outlet port. Since the rotors mesh, they may be distinguished one from the other by calling one the male and the other the female.

The male rotor is directly coupled to, and driven by, a variable speed hydraulic motor. The

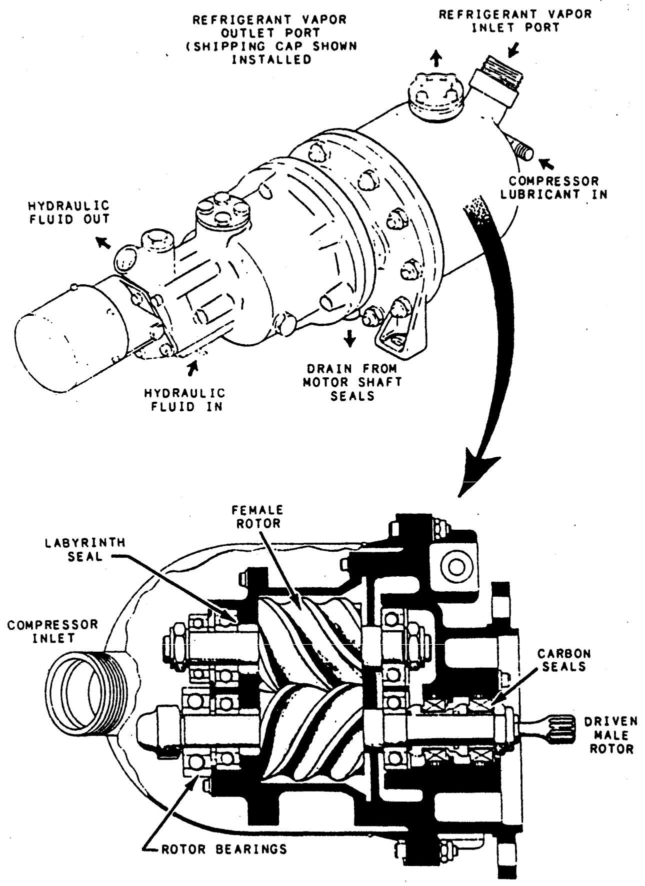

Figure 3-17.—Compressor assembly.

female rotor is driven aerodynamically by the male. There is no physical contact between the two rotors or between the rotors and case. Inter-rotor contact is prevented by the rotors riding on a film of refrigeration oil. Both rotors are suspended by three pairs of ball bearings, one set on the discharge end and two pairs on the inlet end. Bearing lubrication is supplied by the refrigeration oil. Suitable carbon and labyrinth seals are incorporated to provide control of the flow of lubricating oil. Thin ridges are machined on the ends and flutes of the rotors to seal the mechanism against excessive rotor leakage.

The compressor operates on the principle that if a given volume of gas is trapped and the area in which it is contained gradually decreases, the pressure and temperature of the gas will increase. The counterrotating rotors are fed a gas charge from the inlet port. This charge fills the void formed by the rotors. As they rotate, the charge is trapped and forced forward through the housing. The action of the rotors is to decrease the interlobe area in which the charge is contained as they revolve. This increases the pressure and temperature of the refrigerant. As the outlet port is reached, the charge will be contained in the smallest area during its travel through the compressor. Therefore, it is at its highest temperature and pressure and is discharged into the system.

The variable compressor speed is provided by the governor-controlled, hydraulically driven motor, which responds to electronic impulses from the Freon circuit to increase or decrease speed as demanded by the cooling load.

The electrical wiring of the speed-sensing system is such that when the equipment cooling system is shut down, the servomotor will be driven to low speed. This relieves starting loads and also precludes the possibility of an overspeed during startup.

The compressed Freon gas is discharged from the compressor and immediately passes through a check valve, which prevents the high-pressure discharge from motorizing the compressor in reverse at system shutdown.

The compressor section requires lubrication; therefore, an oil is mixed with the Freon during system servicing. This oil is also discharged from the compressor outlet and is reclaimed by the oil separator.

OIL SEPARATOR.— The oil separator is located downstream of the compressor and check valve. It operates on a centrifugal principle; that is, the oil mist refrigerant enters the inlet port of the separator at a tangent to the wall of the cylindrical housing. This imparts a swirling or centrifugal action to the mixture. The centrifugal force has a greater effect on the heavier oil vapors, causing them to collect on the walls and the conical screen. The oil drips from the screen and collects at the bottom of the oil separator.

Oil flows from the bottom of the separator through an oil flow indicator and filter and is injected into the compressor at the shaft seal cavity. The refrigerant vapor rises through the tubular baffle and leaves the separator. A circular sight gauge is provided on the separator to check the level of system oil during operation. Normal oil level is a half full sight gauge.

OIL FLOW INDICATOR.— The oil flow indicator in the oil return line is basically a metal cage with a sight window. It is used to observe the amount of oil returning to the compressor and to prevent compressor failure when no flow is indicated.

OIL FILTER.— Oil returning to the compressor passes through a filter, which ensures a clean oil supply for compressor lubrication. The filter has a replaceable cellulose fiber element. If the filter becomes clogged, a bypass device permits unfiltered oil to circulate through the compressor when the differential pressure across the filter is greater than 18 to 22 psi.

When the differential pressure across the filter is greater than 13.5 to 16.5 psi, the red indicator at the top of the filter will pop up and remain extended to provide an indication that the filter requires replacement prior to becoming completely clogged, and consequently passing contaminant oil to the compressor. The oil filter is designed with an automatic shutoff feature, which permits removal of the filter element and bowl without loss of the refrigerant charge.

CONDENSER EJECTOR AIR SHUTOFF VALVE.— The purpose of the condenser ejector air shutoff valve is to increase airflow across the condenser during ground operation by discharging engine bleed air through the ejector assembly. The valve is pneumatically operated. It is controlled by a piston through a mechanical linkage and is spring loaded to the CLOSED position. A solenoid valve on the actuator chamber side of the piston acts as a bleed off for the air being fed from an upstream tap of the valve housing. This air is fed through the-hollow piston actuator shaft to the top side of the piston where it is bled off as long as the solenoid is de-energized. Energizing the solenoid closes off the actuator chamber bleed, and pressure builds up. This force overcomes spring tension and the valve opens. Any loss of pneumatic or electrical power to the valve will cause it to assume a closed position.

CHARGING VALVES.— There are four backseating charging valves in the vapor cycle system—three in the evaporator group, and one in the condenser group. The valves are used to facilitate servicing of the system as one complete unit or servicing of the evaporator group or condenser group as individual units. The condenser and evaporator group assemblies are equipped with quick-disconnect refrigerant lines to allow their removal from the aircraft without a loss of refrigerant.

PURGE VALVES.— The refrigerant system is equipped with two purge valves—one at the evaporator group assembly high point and the other on the condenser in the top scoop of the aircraft. The valves are similar to the charge valves. They are used to bleed the system, when required, and for attaching test equipment or the vacuum pump for system evacuation.

Maintenance

Maintenance of the vapor cycle ACS, like the air cycle system, will generally require the joint efforts of personnel from the AME and the AE ratings. Malfunctions of the hydraulic motors that drive the compressor and evaporator fan will require the services of an AMH.

Operational checkout of the vapor cycle system can be done in several ways. The AE can perform an operational check of the electrical portion of the system using a Cooling System Test Set, AN/ASM 232 (XN-1), with the engines not running.

Performing an operational check of the complete vapor cycle system without the engines running requires external hydraulic and electrical power and a source of cool air. The cooled air is ducted into the condenser scoop inlet to provide flow through the condenser for condensing the Freon. As was stated earlier, this function is normally done by ram air when sufficient ram airflow is available or by engine bleed air leaving the ejector nozzles and creating a pressure differential that causes sufficient flow for cooling on the ground when the engines are running.

The operational check steps as specified in the applicable MIM should be performed in sequence. If a trouble occurs during a step, it must be corrected before proceeding. Isolation of the trouble can almost always be enhanced by referring to the step of the troubleshooting table that corresponds with the step of the operational checkout where the trouble occurred.

Additional organizational-level maintenance on the vapor cycle system includes servicing (adding refrigerant and lubricating oil), leakage testing and correcting of leaks, and removal and installation of components.

Intermediate-level maintenance of the evaporator assembly, the cindenser group assembly, and the air ejector shutoff valve is restricted to replacement of parts listed in the Spares and Repair Parts Data List provided in the intermediate repair section of the applicable MIM (Part IV). Special test equipment is required to bench test most of the vapor cycle components or assemblies; therefore, not all intermediate-level activities possess the capability to accomplish such maintenance.

Since proper servicing of the vapor cycle system is one of the most important factors affecting operation, equipment used for servicing and servicing procedures are given brief coverage in the following paragraphs.

Servicing Equipment

Servicing of the vapor cycle system involves evacuating and charging the condenser and evaporator group assemblies either separately or preferably together as a system, with refrigerant and/or lubricating oil.

The vapor cycle charging cart (fig. 3-18) is used to replenish the vapor cycle refrigeration system with refrigerant and the compressor with

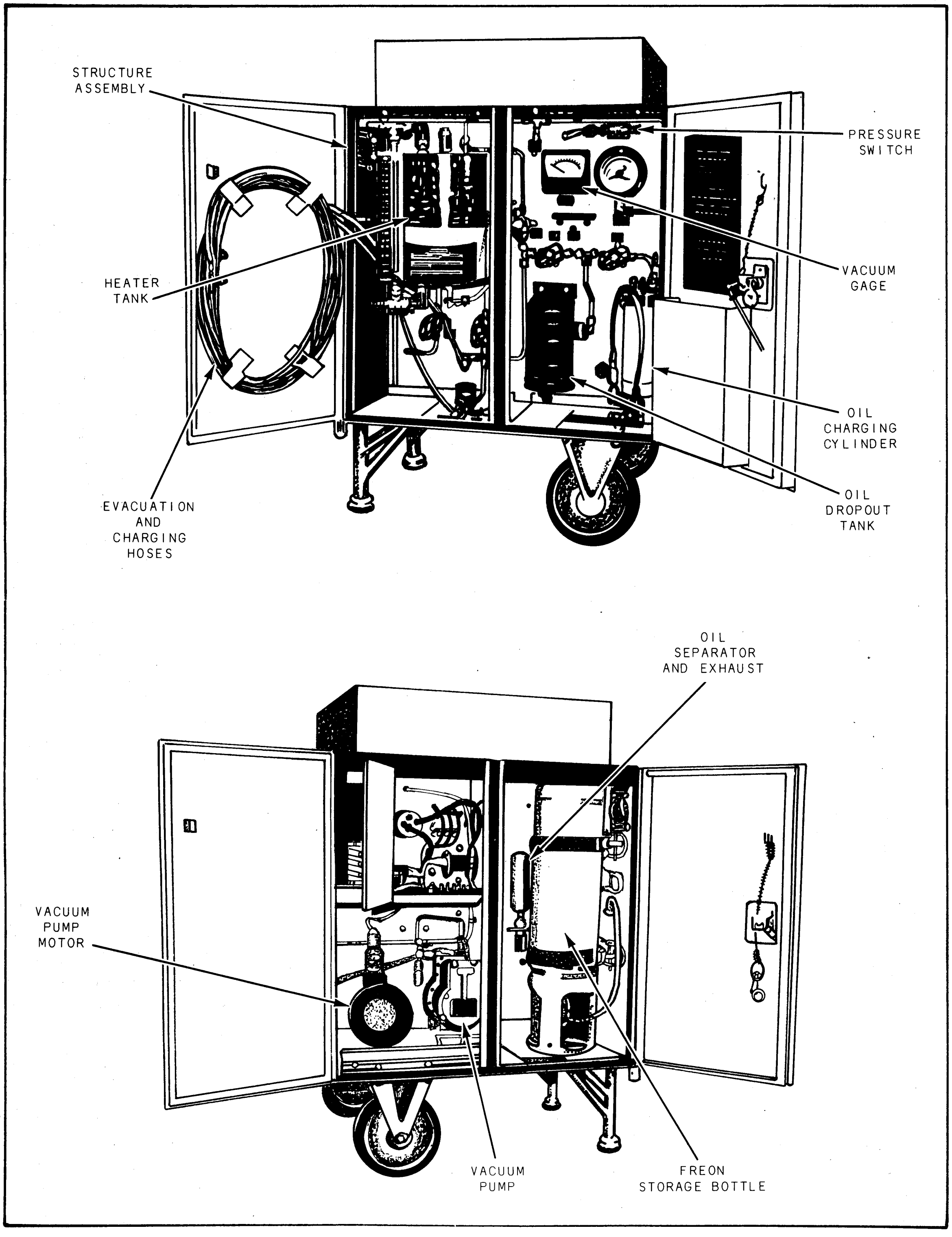

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Figure 3-18.—Vapor cycle charging cart.

lubricating oil. The major components of the cart are labeled in figure 3-18.

The Freon storage bottle has a capacity of 25 pounds of Freon. The bottle is restrained in the cart by quick-release restraining straps, which permit rapid removal and replacement of depleted bottles.

The electric motor-driven vacuum pump is used to evacuate a refrigerant system prior to recharging it with Freon. Evacuating or pulling a vacuum on the system for a short period of time causes any moisture in the system to be vaporized and withdrawn from the system. Moisture in the system, if of sufficient quantity, can freeze at the expansion valve, thus allowing no Freon into the evaporator and cooling would stop.

The vacuum pump has a displacement of 3 cubic feet per minute (cfm) and is rated for continuous duty.

The heater tank has a capacity of 360 cubic inches and an operating pressure rating of 200 psi at 125°F (52°C). A liquid level sight gauge, mounted vertically on the heater tank, indicates the level of liquid Freon in the tank. A scale, graduated in pounds and ounces, is mounted alongside the sight gauge and ranges from 0 to 17 pounds. The tank is also equipped with a compound pressure gauge, which is graduated from 0 to 30 inches Hg (mercury vacuum) and 0 to 300 psi pressure. A heating blanket surrounds the heater tank and is used to heat the refrigerant for building up tank pressure sufficient for charging a system.

The oil charging cylinder stores Ansul 150 lubricating oil used to replenish the vapor cycle compressor oil supply. The cylinder has a capacity of 68 cubic inches and an operating pressure of 100 psi at 125°F. The cylinder is equipped with an oil level sight gauge and an oil charging pressure gauge. A scale, graduated in centimeters, is mounted beside the sight gauge and ranges from 0 to 800 cc.

The flexible evacuation and charging hoses are both 180 inches long to accommodate hooking the cart to the unit being evacuated or charged without removing the unit from the aircraft.

An aircraft power cable connects primary electrical power from the cart to the aircraft. A deck edge power cable or power cable from electric generating equipment provides power to the cart.

Safety Precautions

To prevent injury to personnel and damage to equipment, you must observe the following safety precautions and handling procedures when working with Freon gas:

1. Protective equipment (apron, gloves, goggles, and face mask) must be worn.
2. If liquid Freon comes in contact with the skin, treat the skin for frostbite.
3. If liquid Freon comes in contact with the eyes, medical attention must be sought immediately. The following first aid treatment should be administered: Do not rub or irritate the eyes; drop sterile mineral oil into the eyes; then wash the eyes with a boric acid solution if the irritation continues.
4. Freon is stored in cylinders that are color-coded orange with appropriate lettering for identification. These cylinders should be handled carefully because the pressure inside the cylinder depends upon the ambient temperature. Refrigerant cylinders should not be exposed to high temperatures or flames. Cylinders that are used for high-pressure liquids should never be thrown around, dropped, or used for anything other than their intended purpose. Refrigerant cylinders should never be filled to more than 85 percent of their capacity.
5. Freon tends to dissolve natural rubber; therefore, only the recommended gaskets, O-rings, and packings should be used in the vapor cycle system.

SH-60B HELICOPTER ENVIRONMENTAL CONTROL SYSTEMS (ECS)

Learning Objective: Identify components and conditions of the ECS for the cockpit, cabin area, and the nose avionics compartment of the SH-60B helicopter.

The SH-60B helicopter cabin cockpit and nose bay environments are controlled by the ECS, which provides both heating and air conditioning in a range of 2°C to 71°C. Supplementary or backup air circulation is provided at all crew stations by manually controlled air inlets for outside air.

The ECS (fig. 3-19) consists of an air-cycle machine (ACM) (fan, turbine, and compressor), bleed-air ducting, necessary controls and valves, water separator, distribution system, air inlet, and heat-exchanger exhaust duct. The bleed-air portion of the ECS functions from two sources

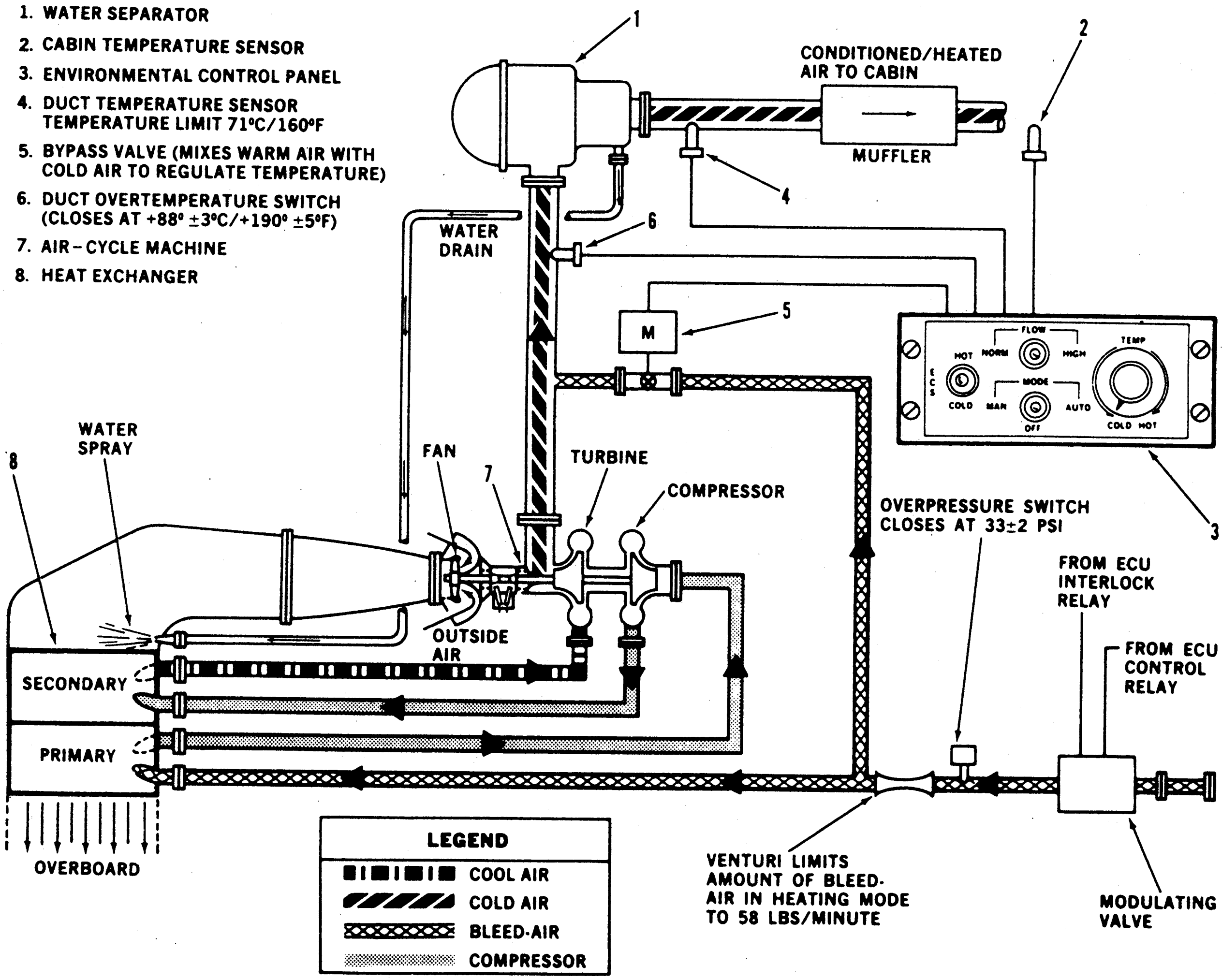


Figure 3-19.—Environmental control system.

of bleed air—engine and auxiliary power unit (APU). The energy extracted from bleed air is used to drive the ACM's cooling fan and compressor. Bleed air is applied to the ACM through a modulating valve, which functions as both an on/off valve and pressure regulator. Air source selection is accomplished by means of the AIR SOURCE ECS/START switch on the overhead control panel. In the ENGINE position, the engine bleed air is selected as a source. In APU position, APU bleed air is used as the air source. With ECS selected ON (from engine source), maximum torque available is reduced by 3.5 percent.

An overpressure switch, located on the ACM side of the modulating valve, senses high air pressure. In an overpressure condition, the over-pressure switch illuminates an advisory panel light to indicate ECS HI PRESS. System shutdown does not occur during an overpressure, since the ACM is capable of withstanding full bleed-air pressure, delivered by the engines or APU. Power is supplied from the No. 2 ac primary bus and the No. 2 dc primary bus, through two circuit breakers, both on the sensor operators (SO) circuit breaker panel, marked ECS PWR and ECS CONTR, respectively. If ECS fails, cooling air must be introduced into the nose avionics compartment by pulling the nose door cooling damper control located on the left-hand side of the console.

ECS CONTROL PANEL

The ECS control panel contains a three-position toggle switch to control the ECS operating modes. At OFF, the switch provides the power to shutoff the system for heating and cooling. At MODE AUTO, the modulating valve is turned on and the cabin temperature is set by the TEMP knob. When at FLOW HIGH, the ECS will operate at high volume from the air-cycle machine. HIGH is used primarily for cooling. Cabin temperature, duct temperature, and the setting of the TEMP knob are all compared in the cabin temperature controller. The MAN position bypasses the cabin and duct control valve by a spring-loaded valve to center HOT-COLD switch. Placing the momentary beep switch to HOT or COLD causes the control valve to move toward open or close as long as the switch is held, allowing manual temperature control.

NOTE: Use of the manual mode of the ECS requires pulsing of the HOT-COLD toggle switch followed by a waiting period to judge the magnitude of temperature change. Excessive manual input may cause ECS shutdown and/or APU failure (if APU is the air source).

The ECS will automatically shut down under the following conditions:

1. Engine contingency power is selected with the contingency-power switch (CNTGY PWR) on either collective stick.
2. In any position of the AIR SOURCE ECS/START switch, when starting either No. 1 or No. 2 engine.

When the AIR SOURCE ECS/START switch is placed to ENGINE, the ECS will also shut down when

1. a turbine gas temperature (TGT) of 856 ± 5°C is reached,
2. either engine ANTI-ICE switch is placed ON, or
3. when the DE-ICE MASTER switch is placed to AUTO and ice is detected.

AVIONICS COOLING

The total aircraft avionics system requires the dissipation of approximately 12 kilowatts of heat. Units cooled by the external air system are maintained at 15° to 27°C. Units cooled by ambient cabin air require an ambient temperature below 29°C.

Two fans provide cooling air for the mission avionics. One fan is located on the right side of the cabin at the base of the mission avionics rack, and the other is located on the left side of the cabin at the base of the sensor operator's (SO's) console. Fan control is provided by the mission power (MSN PWR) switch, located on the lower center console on the MSM SYS (mission systems) panel, and by a 27°C temperature-sensing switch, located at each fan inlet. When the MSN PWR switch is placed in either PRI or SEC position and the fan inlet temperature is above 27°C, the fans run to bring in outside air for circulation through the respective avionics areas. Backup cooling for the avionics is provided by the ECS. If the ECS is operating, the modulating valve will automatically go to the full-open position when the temperature switches at the fan inlets sense a temperature of 54°C or greater. Conditioned cabin air may be circulated through the avionics system by removing the thermal/acoustic panels for backup cooling. Power is supplied from the No. 1 ac primary bus and No. 2 ac primary bus through the (SO) circuit breaker panel by two circuit breakers, marked LH RACT BLOWER and BLOWER, RH RACK.

AIRCRAFT PRESSURIZATION SYSTEMS

Learning Objective: Recognize the purpose and function of aircraft pressurization systems to include maintenance and troubleshooting operations.

As aircraft became capable of obtaining altitudes above that at which flight crews could operate efficiently, a need developed for complete environmental systems.

Air conditioning could provide the proper temperature and supplemental oxygen could provide sufficient breathable air. The one problem was that not enough atmospheric pressure exists at high altitude to aid in breathing, and even at lower altitudes the body must work harder to absorb sufficient oxygen through the lungs to operate at the same level of efficiency as at sea level. This problem was solved by pressuring the cockpit/cabin area.

PRESSURIZATION SYSTEM

The area of an aircraft to be pressurized must be free from all air leaks. This is accomplished by the use of seals around tubing, ducting, bolts, rivets, and other hardware that pass through or pierce the pressuretight area. All panels and large structural components are assembled with sealing compounds. Access and removable doors and hatches have integral seals. Canopies are constructed with inflatable seals. The pressurizing air is the air from the aircraft ACS.

The S-3 aircraft incorporates a cabin pressurization subsystem. This subsystem regulates the outflow of air from the cabin to control the cabin pressure according to a predetermined schedule. Cabin air is drawn through the internal avionics racks by the cabin exhaust fan and is modulated by the cabin pressure regulator valve. A cabin pressure regulator control provides the pressurization schedule.

System Operation

The cabin pressurization subsystem is governed by the pressure regulator control, which provides five modes of operation: unpressurized, isobaric, differential cabin-to-ambient pressure, dump, and repressurization.

Below 5,000 feet, the cabin is normally unpressurized. Between 5,000 and 25,000 feet, the cabin altitude will remain at 5,000 feet. Maximum cabin pressure-to-ambient differential is 6.7 ± 0.1 psi. Table 3-1 displays various cabin pressure differentials and cabin altitudes for different flight levels.

During the unpressurized mode of operation, the pressure regulator control directs low-pressure air to the pressure regulator valve to command it to the full open position. This mode of operation occurs at all altitudes below 4,350 feet. In this mode, cabin pressure is maintained at a near ambient pressure. The pressure is slightly above ambient because of the duct pressure losses, the quantity of air flowing into the cabin, and the pressure across the internal avionics ventilation subsystem.

During flight operations between 5,000 and 24,000 feet, the isobaric mode maintains the cabin altitude between 4,350 and 5,000 feet. The pressure regulator control, using the sensed ambient pressure as a low-pressure source and the sensed cabin pressure as the high-pressure source, modulates the pressure regulator open or closed to maintain cabin pressure at the specific altitude.

The differential mode of operation overrides the isobaric mode of operation when the aircraft is flying at altitudes in excess of 24,000 feet. As cabin-to-ambient differential pressure reaches 6.7 ± 0.1 psi, a spring-loaded diaphragm in the pressure regulator control positions a poppet valve to supply this differential pressure as a control pressure to the pressure regulator valve. The pressure regulator valve compares this control pressure to cabin pressure, and it positions

Table 3-1.—Cabin Altitude versus Flight Altitude Schedule

Flight Altitude (ft)	Cabin Pressure Differential		Cabin Pressure Altitude	
	Min (psi)	Max (psi)	Min (ft)	Max (ft)
0	0	0.25	−500	0
5,000	0	0.30	4,350	5,000
10,000	2.12	2.42	4,350	5,000
15,000	3.94	4.24	4,350	5,000
20,000	5.48	5.78	4,350	5,000
*24,300	6.60	6.80	4,500	5,000
25,000	6.60	6.80	5,000	5,380
30,000	6.60	6.80	7,400	7,870
35,000	6.60	6.80	9,600	10,100
40,000	6.60	6.80	11,520	12,050
*Maximum flight altitude for a 5,000 ft cabin altitude				

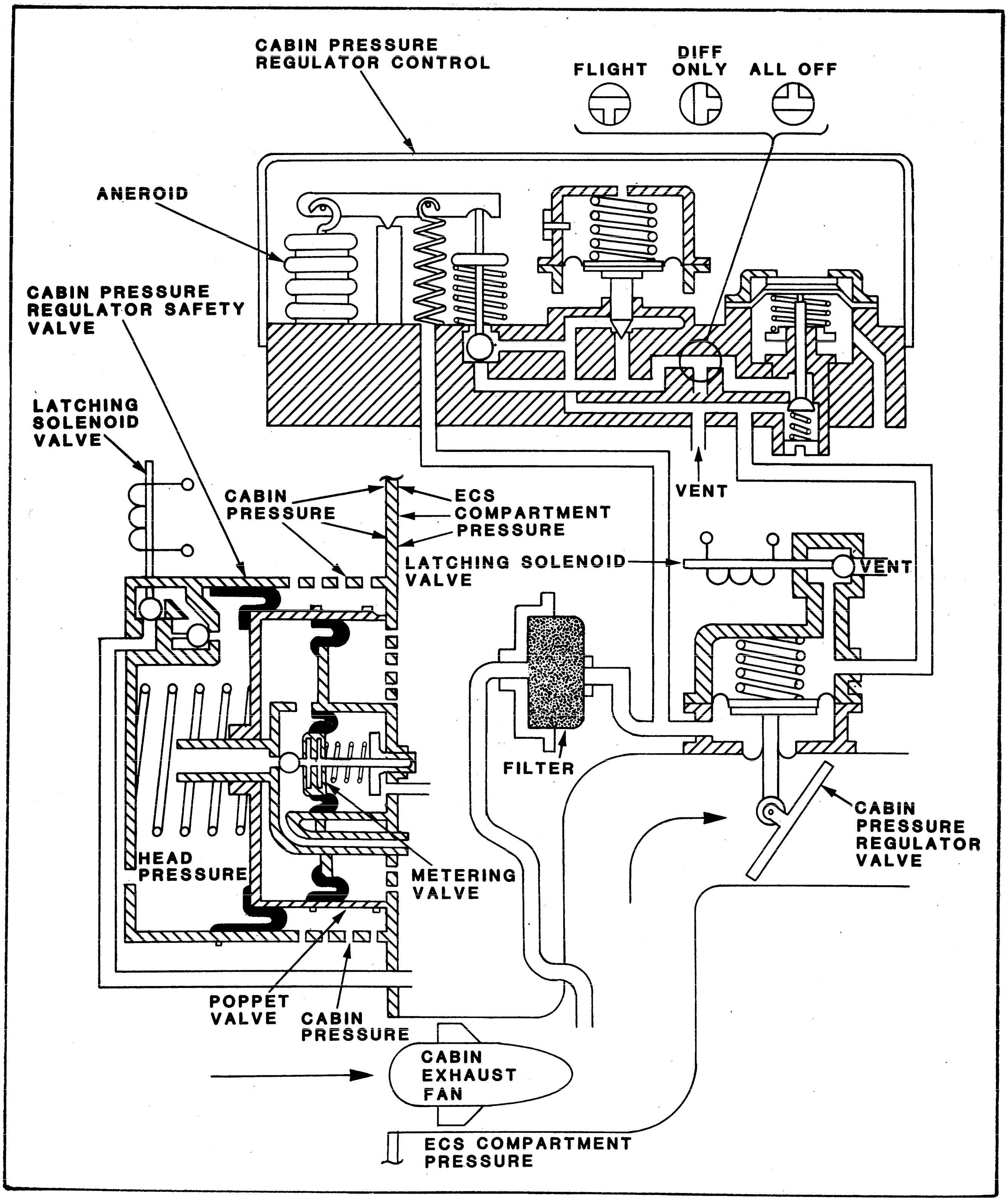


Figure 3-20.—Cabin pressurization subsystem schematic.

the butterfly valve to maintain the required differential pressure.

The cabin pressurization system also makes provision for dumping cabin pressure in an emergency. By setting the cabin pressure switch on the environmental control panel to the DUMP position, the latching solenoids on both the cabin outflow pressure regulating valve and on the cabin safety valve are actuated to the dump position. In addition, the recirculation air shutoff valve will be actuated to the full open position, provided electrical power is available. A secondary method of achieving cabin depressurization is to turn the air-conditioning switch to the OFF/RESET position and select the auxiliary vent mode. This selection will cause the cabin outflow pressure regulator valve to open, but it will not actuate the cabin safety valve to the open position.

The repressurization mode of operation is used when returning to the normal mode from the dump mode or during a rapid descent in excess of 4,000 feet per minute. In this mode, the pressure regulator control modulates the rate of cabin repressurization with an integral isobaric and differential pressure control system. The pressure regulator control compares the existing cabin pressure to a lagging cabin pressure reference. If the result of this comparison exceeds the calibrated rate, control pressure output from the pressure regulator control is reduced. This causes the pressure regulator valve to sense a relatively higher pressure on the opening side of its actuating diaphragm, thus allowing the diaphragm to open the pressure regulator valve butterfly. This reduces cabin pressure and the rate of repressurization.

Precautions for operating the S-3 cabin pressurization subsystem on the ground, where the elevation is 5,000 feet or higher, are required because the cabin pressurization subsystem does not have provisions for automatic repressurization. Therefore, the cabin will be pressurized whenever the ground elevation is above 5,000 feet.

To ensure adequate cooling of the internal avionics during operations at ground elevations above 5,000 feet, one of the following steps must be used:

1. Keep the cabin pressurized as in flight.
2. Set the cabin pressure switch to DUMP to ensure a full-open pressure regulator valve and a full-open pressure safety valve.
3. If the outside air temperature is below 80°F, turn the auxiliary vent selector to ON and open the cabin entry door.

Component Description

The S-3 cabin pressurization subsystem consists of five primary components. Four of them are shown in figure 3-20. The fifth component is located in the cockpit. Each component is discussed in the following paragraphs. If you are to troubleshoot effectively, it is important to know the relationship of each component to the system as a whole.

CABIN PRESSURE REGULATOR VALVE.— The cabin pressure regulator valve is a pneumatically actuated butterfly valve mounted in the cabin exhaust ducting downstream of the cabin exhaust fan. The butterfly is spring-loaded to the closed position and diaphragm operated to the open position. The pressure regulator valve consists of the butterfly valve, which is actuated by a pressure-controlled diaphragm, and a solenoid valve to control the air pressure on the diaphragm. The solenoid valve is electrically connected to the cabin pressurization switch on the environmental control panel (fig. 3-21).

There are three ports leading into the pressure regulator valve diaphragm chamber (fig. 3-20). The first port is located on the spring-loaded closing side of the diaphragm. It admits pressure from the cabin pressure regulator control. The second port is the ambient vent port. It is also located on the spring-loaded closing side of the

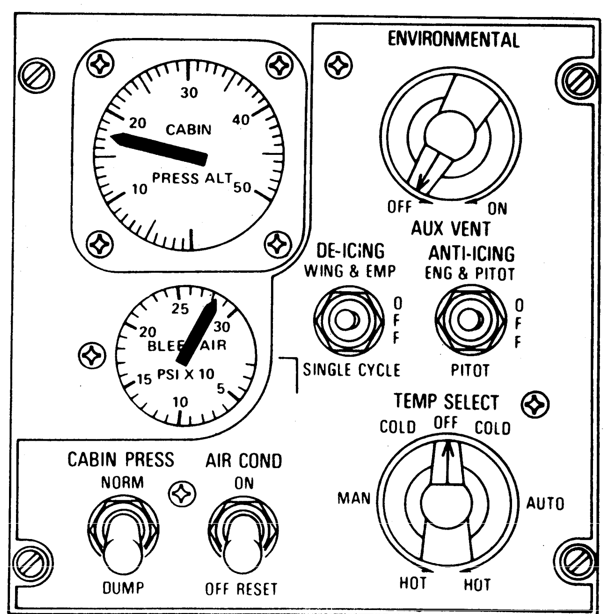


Figure 3-21.—Environmental control panel.

diaphragm. The third port is located on the opening side of the diaphragm. A sensing line is attached to the third port to connect the cabin pressure regulator control and the cabin pressure exhaust duct. The pressure admitted to the diaphragm through the third port is equivalent to cabin air pressure. The difference between the pressure on either side of the diaphragm causes the pressure regulator valve to modulate between the open and closed positions.

CABIN PRESSURE REGULATOR SAFETY VALVE.— The pressure regulator safety valve is an independent, pneumatically operated, balanced type of poppet valve that limits cabin-to-ambient pressure differentials to 7.07 (+0.2 and – 0.0) psi. If the difference between cabin pressure and ambient pressure reaches the calibrated limit, the change in pressure acting on the limit control diaphragm overcomes the metering valve spring-load and allows the metering valve to open. This also opens a passage in the cabin pressure safety valve head, which causes the head pressure to be slightly lowered. Since the cabin pressure is greater than head pressure, it opens the pressure-balanced main poppet to allow cabin air to be vented overboard. When the cabin pressure differential is restored to normal, the limit control metering valve closes, and the pressure safety valve returns to its normally closed position.

CABIN PRESSURE REGULATOR CONTROL.— The pressure regulator control is a pneumatic control that provides four modes of cabin pressure operation. In addition to the modes of operation, a test valve is included with three manually set positions: FLIGHT, DIFF ON, and ALL OFF. The test valve is normally lockwired in the FLIGHT position for all cabin pressurization modes. The DIFF ON position permits aground test of the normal delta-P setpoint. The ALL OFF position permits a ground test of the setpoint of the pressure safety valve. These tests are accomplished with pressure supplied by support equipment.

Four pneumatic ports are provided on the pressure regulator control for use with various sensed pressures and the pressure regulator valve. These ports are different sizes to prevent improper plumbing connections.

The pressure regulator control contains an isobaric bellows, which is calibrated to maintain an aircraft cabin pressure of 5,000 feet while the aircraft is flying at altitudes between 5,000 and 24,000 feet. The isobaric bellows, which modulates a control pressure, use cabin air as a pressure source and low pressure in the environmental control system compartment as a negative pressure. Control pressure is delivered to one side of the pressure regulator valve diaphragm, and cabin pressure is connected to the opposite side. Because control pressure is normally less than cabin pressure and will decrease relative to cabin pressure, the pressure regulator valve becomes more open to decrease cabin pressure.

The pressure regulator control contains provisions for controlling the rate of cabin repressurization when recovering cabin pressure after using the cabin dump mode, or during a rapid descent in altitude. The control pressure modulated by the isobaric bellows is further modulated by the repressurization diaphragm to limit cabin repressurization to an equivalent 4,000 feet per minute change. The pressure regulator valve is held open until normal pressure characteristics are sensed.

CABIN LOW-PRESSURE SWITCH.— The low-pressure switch is installed below the center console to sense the cabin absolute pressure. The normally open low-pressure switch closes at 13,000 ± 500 feet and reopens at 11,000±500 feet. The cabin pressurization indicator light on the annunciator panel illuminates when the low-pressure switch closes. The indicator light goes off when the low-pressure switch reopens.

CABIN AIR PRESSURE SENSING FILTER.— The air pressure sensing filter is located in the line that connects the cabin exhaust air duct, the cabin pressure regulator control, and the cabin pressure regulator valve. The replaceable filter element, which is connected to the air sensing tube, is mounted with clamping rings on the fuselage frame. The filter element is a cylindrical plug of treated paper and fabric in a metal housing. The clamping rings confine the air entry to the dome-shaped end to trap the entry of tobacco tar and dust particles greater than 10 microns in diameter.

MAINTENANCE AND INSPECTION

Very little maintenance is required on most pressurization and ACSs other than making the required periodic inspections and operational checks. Many of the components are repairable at the depot level of maintenance rather than at lower levels of maintenance because of the high cost of special equipment required for making adjustments necessary to proper operation.

In most instances, a maladjusted or malfunctioning component must simply be removed and replaced. There are, however, certain components that require periodic servicing, cleaning, and inspection so the component will function properly and efficiently and may be considered reliable for flight. Specific requirements for servicing, cleaning and inspection are listed in the daily, postflight, and special/conditional, Maintenance Requirements Card (MRC) decks as well as the MIM for each aircraft.

Electrical Failures

Since all pressurization and ACSs have electrically controlled components, maintenance of these systems must include the related electrical circuits. Although an AE is generally called upon to locate and correct electrical troubles, the AME should be able to check circuits for loose connections, and even perform continuity checks when necessary. A knowledge of electrical symbols and the ability to read circuit diagrams is therefore necessary. Figure 3-22 illustrates the electrical symbols commonly found in schematic diagrams.

Loose connections are located by checking all connectors in the circuit. A connector that can be turned by hand is loose and should be tightened handtight.

A continuity check is simply a matter of determining whether or not the circuit to the valve, or other electrically controlled unit, is complete. The check for continuity may be made with a test lamp, which can be drawn from supply.

To perform a continuity check, the connector at the electrically controlled unit is first disconnected. Then, with all necessary switches and circuit breakers closed, the test lamp is connected into the circuit at the electrical connector. The lamp thus indicates whether or not the circuit is complete.

Continuity checks may also be made with the use of a multimeter. A multimeter is an instrument used for measuring resistance, voltage, or amperage.

Troubleshooting

Troubleshooting is the process of locating a malfunctioning component or other unit in a

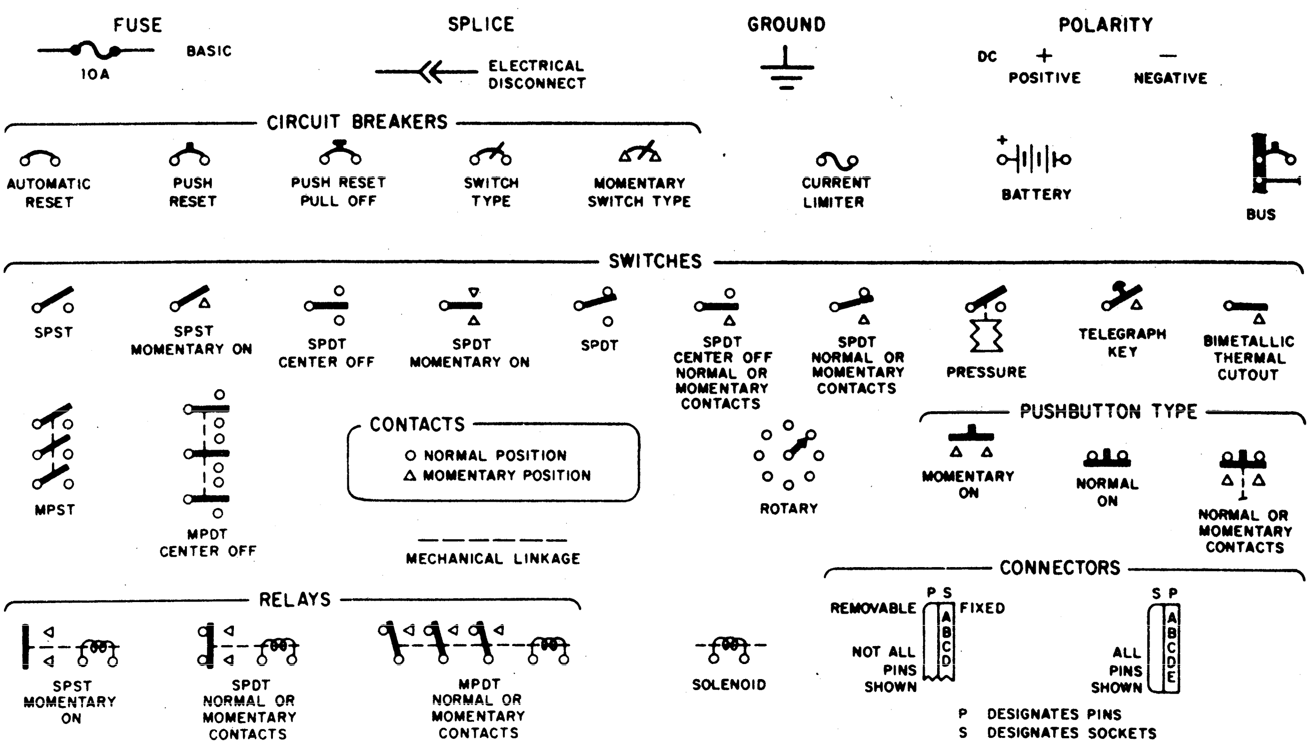


Figure 3-22.—Electrical symbols.

system or mechanism. For the AME, troubleshooting is an important responsibility and one to which he/she will devote a lot of squadron time.

When a malfunction is reported concerning any of the components or systems that are maintained by the AME, he/she must be able to locate the trouble and correct the difficulty.

To troubleshoot intelligently, the AME must be familiar with the system(s) at hand. He/she must know the function of each component in the system and have a mental picture of the location of each component in the system in relation to other components, as well as the location of the component in the aircraft. This can be best achieved by studying the installation and schematic diagrams of the systems found in the applicable MIM.

Troubleshooting procedures are similar in practically all applications. The procedures covered in this section are adaptable to almost all aircraft systems. Auto mechanics use these steps to find and repair automobile malfunctions. The AME can use these procedures to find and repair malfunctions within all the aircraft system for which he/she is responsible.

Basically, there are seven distinct steps to follow during troubleshooting. These steps are as follows:

1. Conduct a visual inspection. This inspection should be thorough and searching—checking all lines, linkages, and components for obvious damage, evidence of leakage, looseness, security, material condition, and proper installation; and servicing when applicable.

2. Conduct an operational check. The malfunctioning system or subsystem is checked for proper operation. This may be accomplished by using special support equipment such as the environmental control test set or by using aircraft power and equipment with the engines running. Each aircraft maintenance manual provides the steps to be taken in performing the operational checkout of all the aircraft's systems. The operational checks and troubleshooting charts for each system are numbered so that when a malfunction occurs during a step in the operational checkout, the malfunction can be located under the same step number in the troubleshooting chart. The troubleshooting chart will provide a list of the most probable causes of the malfunction in the order of probability, along with a recommended remedy. In any case, the AME must check the system out thoroughly, observing proper operation, sequence of events, etc.

3. Classify the trouble. Malfunctions usually fall into three basic categories—electrical, mechanical, and/or improper installation. Using the information acquired in steps 1 and 2, the AME determines under which category the malfunction occurs. Proper use of the test set or a multimeter will identify whether the trouble is electrical or mechanical. Use of the MIM when performing all maintenance tasks should prevent improper installation. Something affecting the flow of gas or liquid (as could be the case in the vapor cycle ACS) could be categorized as a combination electrical/mechanical failure. Most mechanical failures should be found on the visual inspection; however, drive shaft failure on some of the air-conditioning valves is not readily apparent until the valve is operated. In some cases it may even be necessary to disconnect the valve from the ducting so that the butterfly valve can be observed through the end opening. The position indicator on some valves can indicate that the valve is changing positions, which would be a false indication if the shaft was broken after the indicating mechanism, or if the butterfly valve was damaged in such a manner that the shaft would rotate without actually repositioning the valve.

4. Isolate the trouble. This step calls for sound reasoning and a full and complete knowledge of how each component and the system should operate. During this step, the AME can make full use of his knowledge and the system schematics to trace system operation and systematically eliminate components. He can then arrive at a reasonable conclusion concerning the cause of the malfunction based on facts and deductive reasoning. Usually the trouble can be pinned down to one or two areas. By checking each individual area or component, the trouble can be isolated.

5. Locate the trouble. This step is used to eliminate unnecessary parts removal, thus saving time, money, and man-hours. Once the AME has isolated the trouble to a certain area or component, a closer observation of the valve or component in operation should provide some obvious indication that it is not operating as specified in the MIM. If all evidence indicates that the problem is electrical, the assistance of an AE should be requested.

6. Correct the trouble. This step is performed only after the trouble has been definitely pinpointed and there is no doubt that the AME's diagnosis is correct. Removal, replacement, or repair of the unit or system is done using the

instructions provided in the applicable aircraft MIM.

NOTE: While performing maintenance on any system, ensure that the step-by-step procedures outlined in the MIM including CAUTIONS, WARNINGS, and SAFETY notes concerning the specific procedures are strictly complied with.

7. Conduct a final operational check. The affected component or system must be given an operational check following installation or repair to verify proper system or component operation. The MIM will provide the procedures for conducting the operational check. It will usually require operation of the system in various modes (manual and automatic for air-conditioning and pressurization systems) or through several cycles, as applicable. Specified steps throughout the repair procedure and operational check must be observed and certified by a quality assurance representative or a collateral duty quality assurance representative from the work center performing the work. These steps are usually identified in the MIM by underlining, italics, or some other obvious method.

MULTIMETER TROUBLESHOOTING SKILLS

As previously mentioned, much of the AME's time is spent troubleshooting equipment in the squadron's aircraft. Troubleshooting on the S-3 aircraft environmental control system involves the use of the multimeter to check the resistance of the temperature sensor and to check the voltage to electrical connectors. The material presented in the following paragraphs will increase your knowledge of the multimeter and increase your proficiency as a troubleshooter. If you are not sure of the proper and safe methods for using this equipment, you should request the assistance of an AE.

Multimeter

A multimeter is the most common electrical measuring device used in the Navy. The name multimeter comes from the words MULTIple METER. The multimeter is a direct current (de) ammeter, an alternating current (at) ammeter, a dc voltmeter, an ac voltmeter, and an ohmmeter all in one package. Figure 3-23 is a sketch of a typical multimeter. While it may look complicated, it is very easy to use.

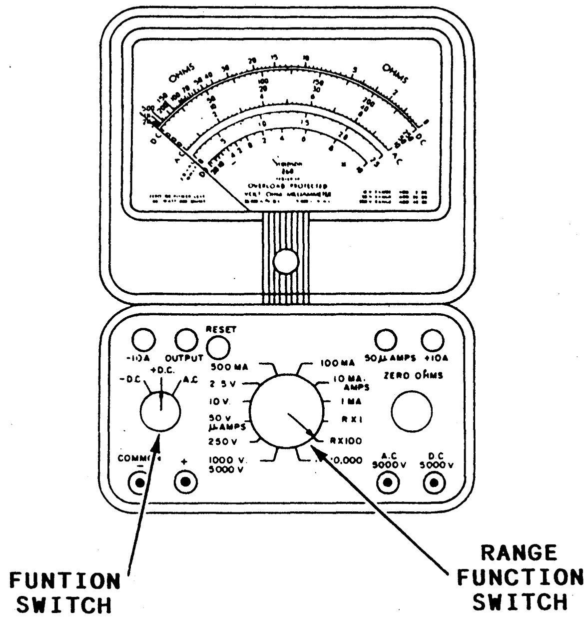


Figure 3-23.—A typical multimeter.

JACKS.— The lower portion of the meter contains the function switches and jacks for the meter leads. The COMMON or (–) jack is used in most functions of the meter. One meter lead is plugged into the common jack. The (+) jack is used for the second meter lead for any of the functions printed beside the range function switch (the large switch in the center). The other jacks have specific functions printed above or below them and are self-explanatory. The output jack is used with the dB scale and will not be explained. To use one of the special function jacks, except the + 10 amps, one lead is plugged into the common jack, and the range function switch is positioned to point to the special function desired.

For example, to measure a very small current (20 microampere), one meter lead is plugged into the common jack, the other meter lead is plugged into the 50 amps jack, and the function switch is placed in the 50V/u amps position. To measure currents above 500 milliamperes, the + 10A and – 10A jacks are used for the meter leads, and the function switch is placed in the 10MA/AMPS position.

FUNCTION SWITCHES.— The function switch is used to select the function desired. The – dc, + dc, ac switch selects director alternating current and changes the polarity of the direct current functions. To measure resistance, this switch should be in the + dc position.

The zero ohms control is a potentiometer for adjusting the 0 reading on ohmmeter functions. The reset is a circuit breaker and is used to protect the meter movement. Not all multimeters have this protection, but most have some sort of protection, such as a fuse.

When the multimeter is not in use, it should have the leads disconnected and be switched to the highest voltage scale and ac. These switch positions are most likely to prevent damage if the next person using the meter plugs in the meter leads and connects them to a circuit without checking the function switch and the dc/ac selector.

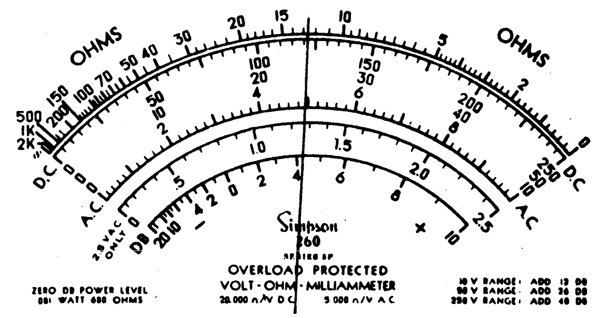
SCALES.— The numbers on the uppermost scale in figure 3-24 are used for resistance measurement. If the multimeter was set to the R x 1 function, the meter reading would be approximately 12.7 ohms.

The numbers below the uppermost scales are used for de voltage and current. These numbers are also used with the scale just below them for ac voltage and current. The fourth scale from the top and the numbers just below the scale are used for the 2.5-volt ac function only. The lowest scale (labeled dB) is not discussed. Figure 3-24 shows how the given needle position should be interpreted with various functions selected.

Multimeter Safety Precautions

As with other meters, the incorrect use of a multimeter could cause injury or damage. The following safety precautions are the minimum for using a multimeter:

1. De-energize and discharge the circuit completely before connecting or disconnecting a multimeter.
2. Never apply power to the circuit while measuring resistance with a multimeter.
3. Connect the multimeter in series with the circuit for current measurements, and in parallel for voltage measurements.
4. Be certain the multimeter is switched to ac before attempting to measure ac circuits.
5. Observe proper dc polarity when measuring dc
6. When you are finished with a multimeter, switch it to the OFF position, if available. If there is no off position, switch the multimeter to the highest ac voltage position.
7. Always start with the highest voltage or current range.



FUNCTION SWITCH	-D.C./+D.C. A.C.	INDICATION
5000 V	+ d.c.	+ 2420.00Vd.c.
1000 V	− d.c.	− 482.00Vd.c.
250 V	+d.c.	+ 121.00Vd.c.
50 V	a.c.	24.90Va.c.
10 V	a.c.	4.99Va.c.
2.5 V	a.c.	1.28 Va.c.
10 A	+d.c.	4.82 Ad.c.
500mA	a.c.	249.00mAa.c.
100mA	a.c.	49.90mAa.c.
10mA	+d.c.	4.82mAd.c.
50μA	+d.c.	24.20μAd.c.
R x 100	+d.c.	1.27 kΩ

Figure 3-24.—A multimeter scale and readings.

8. Select a final range that allows a reading near the middle of the scale.
9. Adjust the 0 ohms reading after changing resistance ranges and before making a resistance measurement.
10. Be certain to read ac measurements on the ac scale of a multimeter.
11. Observe the general safety precautions for electrical and electronic devices.

All valves are not constructed in the same manner. Therefore, the electrical tests performed on a valve should be accomplished as directed by the appropriate MIM. The voltage and resistance tests described in the following paragraphs are examples and should not be used as references for the performance of tests on aircraft.

VOLTAGE TEST.— To perform a voltage test of the S-3 bleed-air shutoff valve, you must first secure power to the valve. Set the function switch of your multimeter to the + dc position. Set the range select switch to the 50V position. Next, insert the black test lead in the (–) common jack and the red lead in the (+) jack.

Before proceeding, you should review the appropriate MIM for the correct placement of the test lead probes with respect to the connector pins. You should also review the voltage requirements for a successful test. Finally, you should ensure that all circuit breakers and switches are in the correct position.

After applying power to the connector, be sure that you are using the correct meter scale to obtain the voltage reading. In this example, you would use the 50 dc scale. With the test completed, you should return to the MIM for the remainder of the steps in the troubleshooting procedure.

RESISTANCE TEST.— To perform a resistance check on an S-3 cabin temperature sensor you must secure power to it. Then, ground the sensor to remove any voltage that may remain in the circuit. Set the function switch to the + dc position. Set the range select switch to the R x 100 position. Next, insert the black test lead in the(–) common jack and the red lead in the (+) jack.

With the power removed and the meter preset, short the test leads by touching them together. Then place the meter in a horizontal position and rotate the 0 ohms control until the meter indicates zero. It is important to keep the meter in the same position for the entire test to ensure accurate readings.

NOTE: The function switch may have to be reset to keep the resistance reading near the mid-scale point.

Because ambient temperature affects the resistance of the sensor, you should refer to the air temperature versus resistance schedule chart of the MIM to obtain the prescribed resistance readings. The MIM should also be consulted for the proper multimeter probe placement on the sensor. For this example, your resistance readings is read from the top scales (ohms) as shown in figure 3-24.

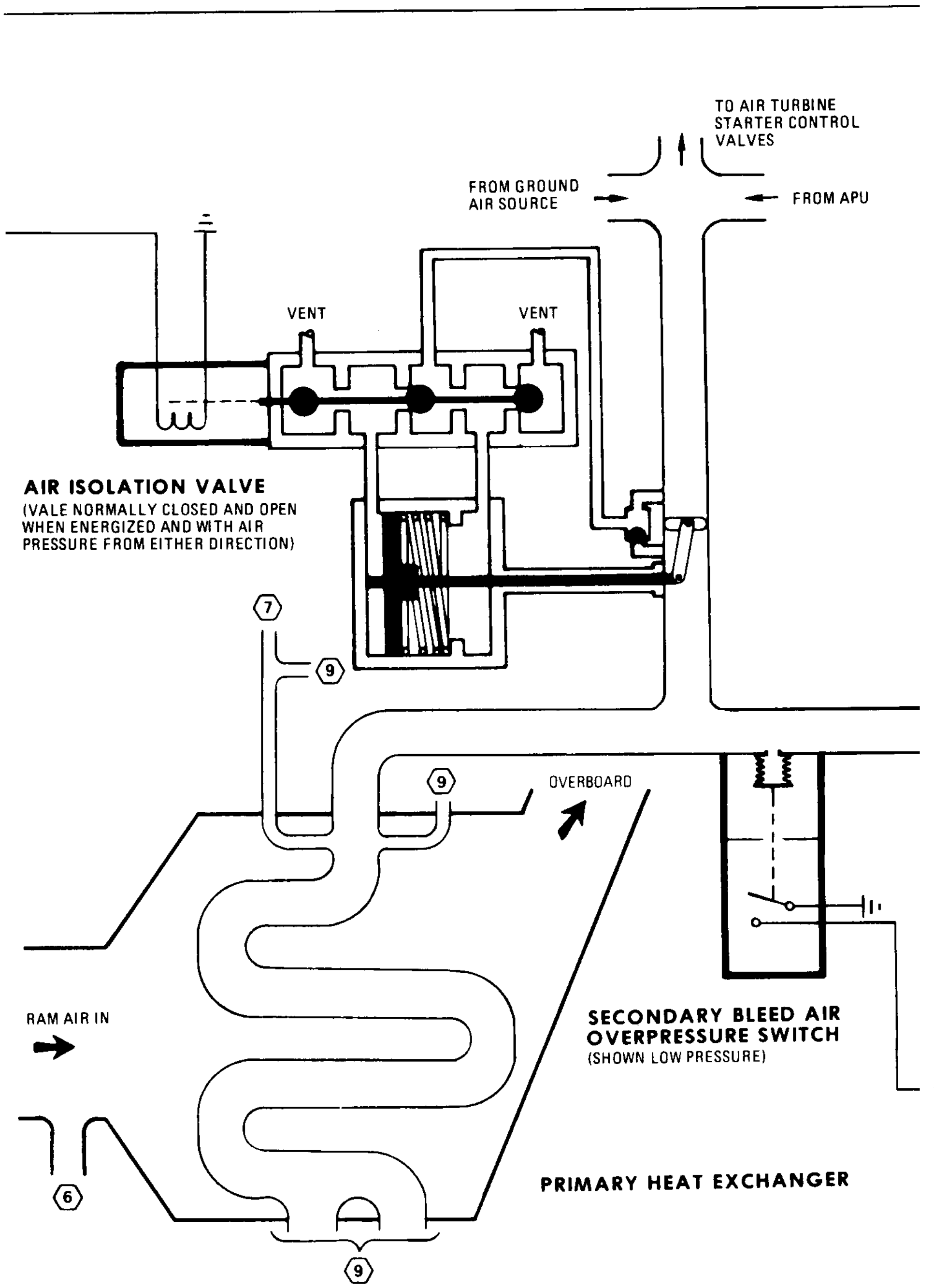


Figure 3-1A.—Bleed-air system.

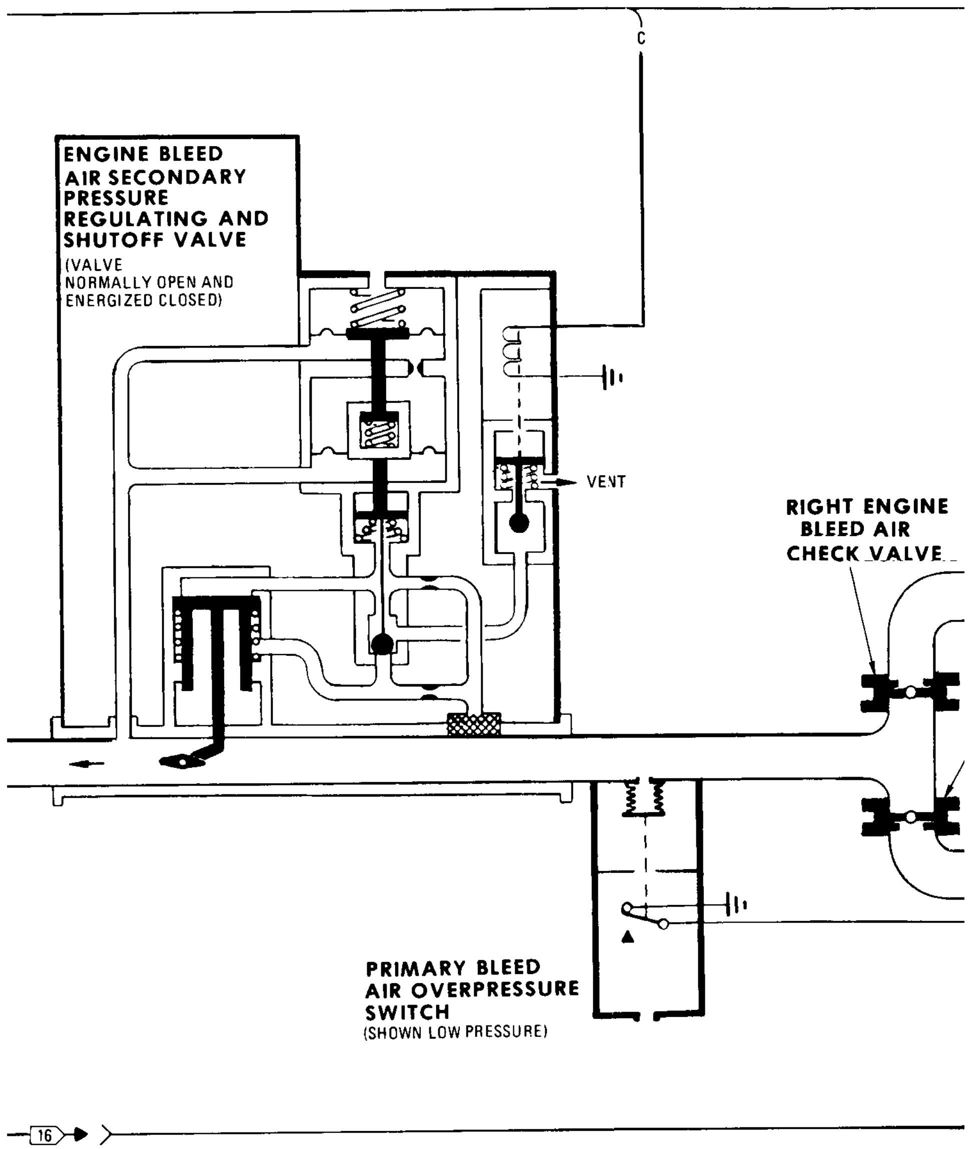


Figure 3-1B.—Bleed-air system-Continued

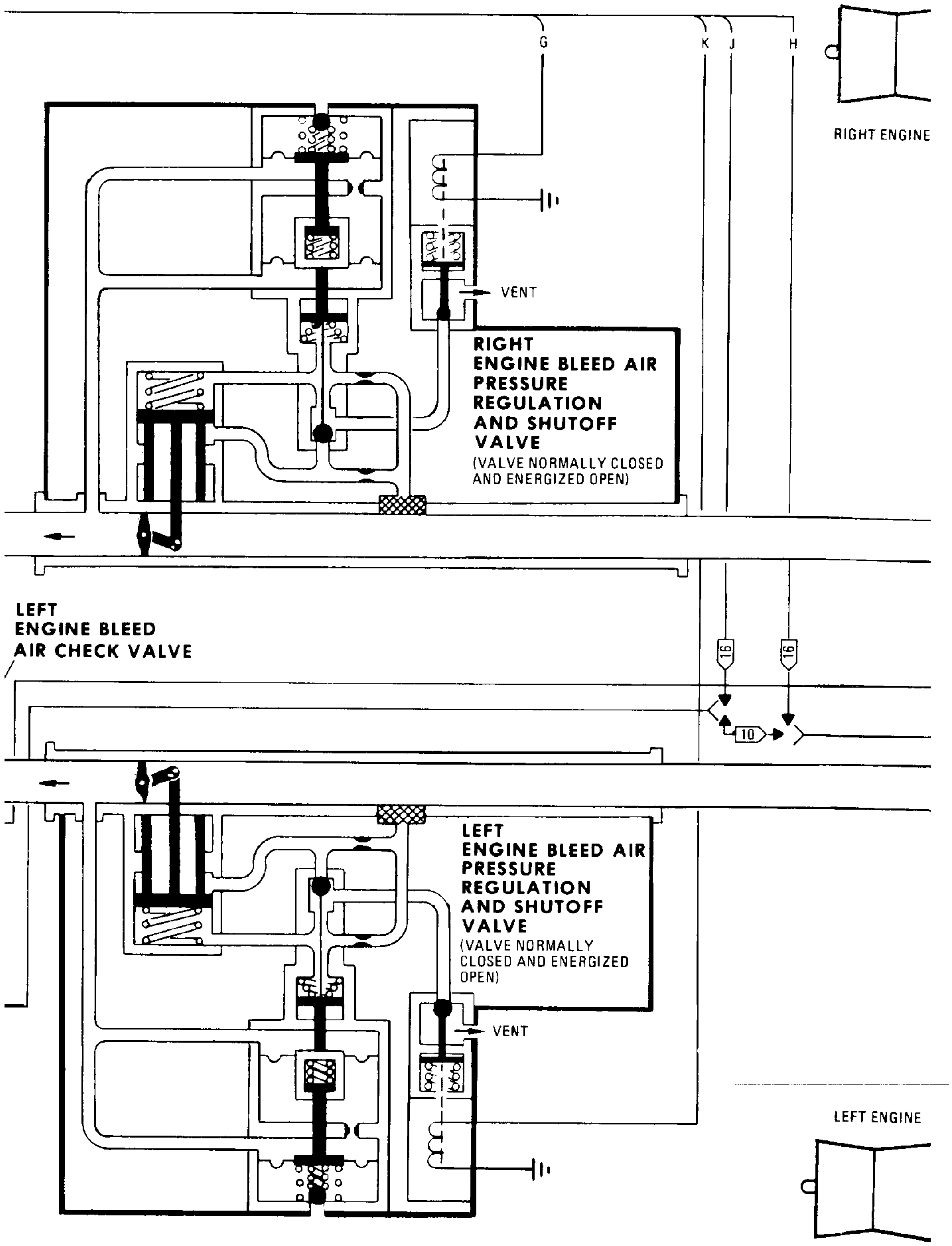


Figure 3-1C.—Bleed-air system-Continued

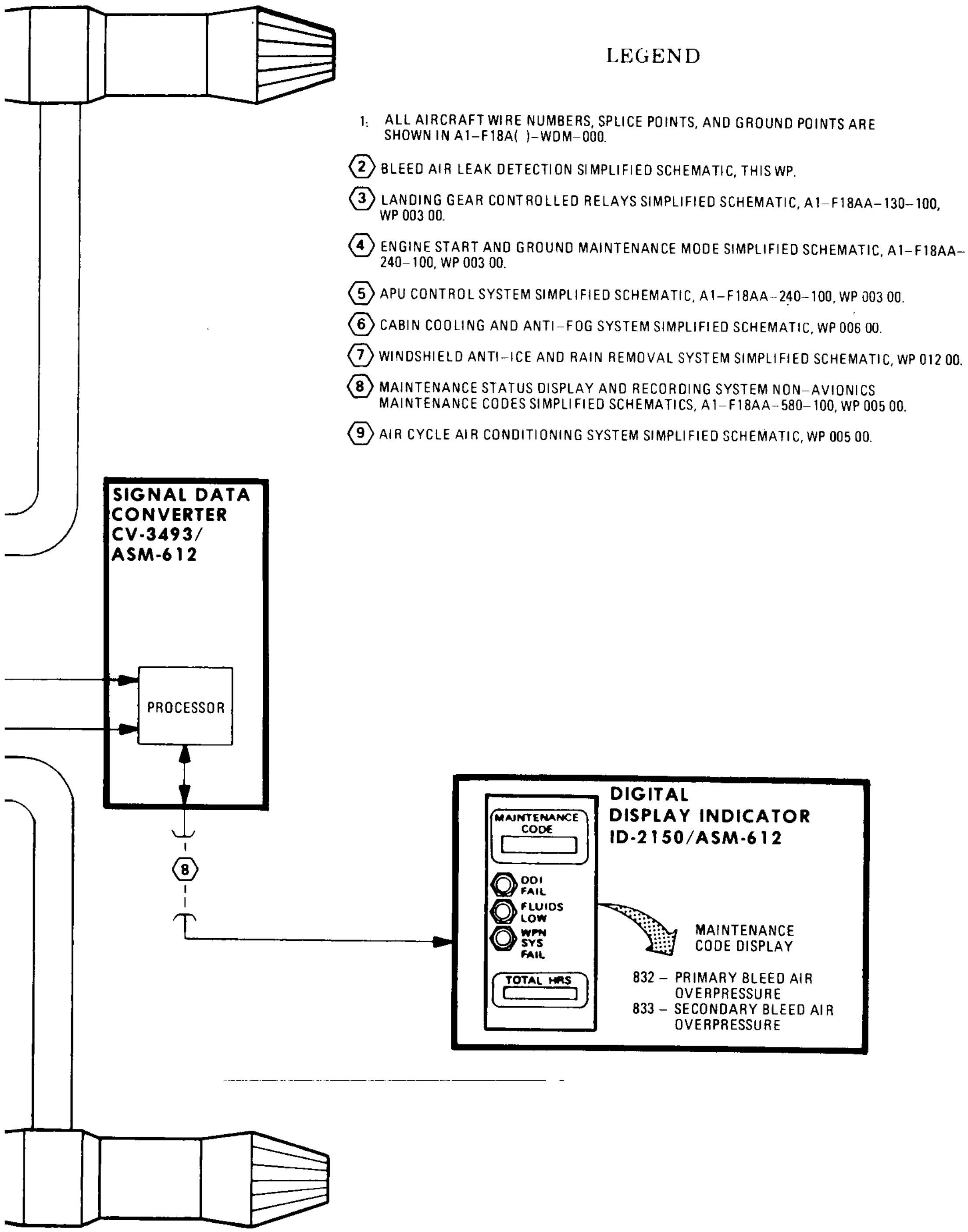


Figure 3-1D.—Bleed-air system-Continued

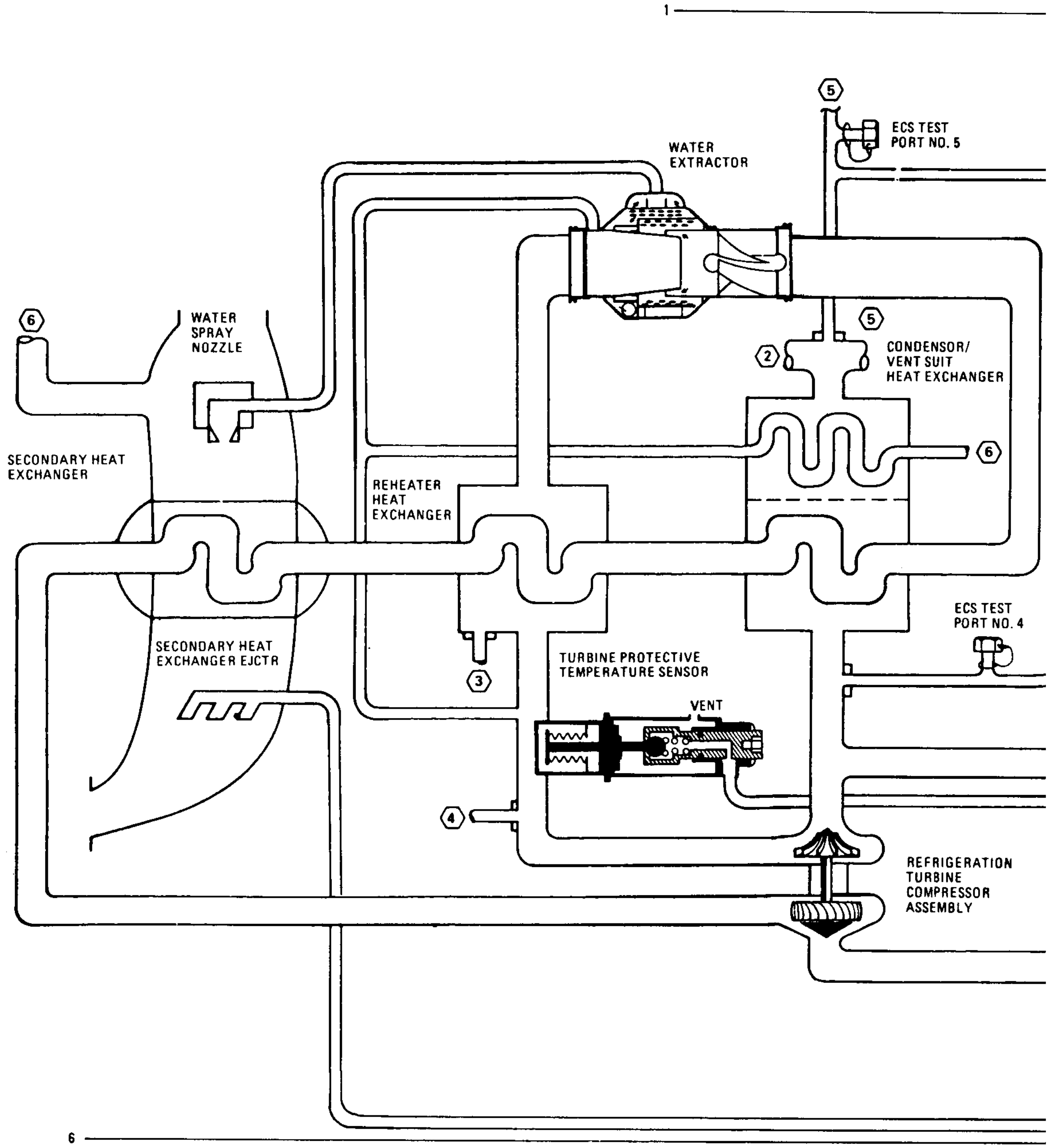


Figure 3-2A.—Air cycle air-conditioning system.

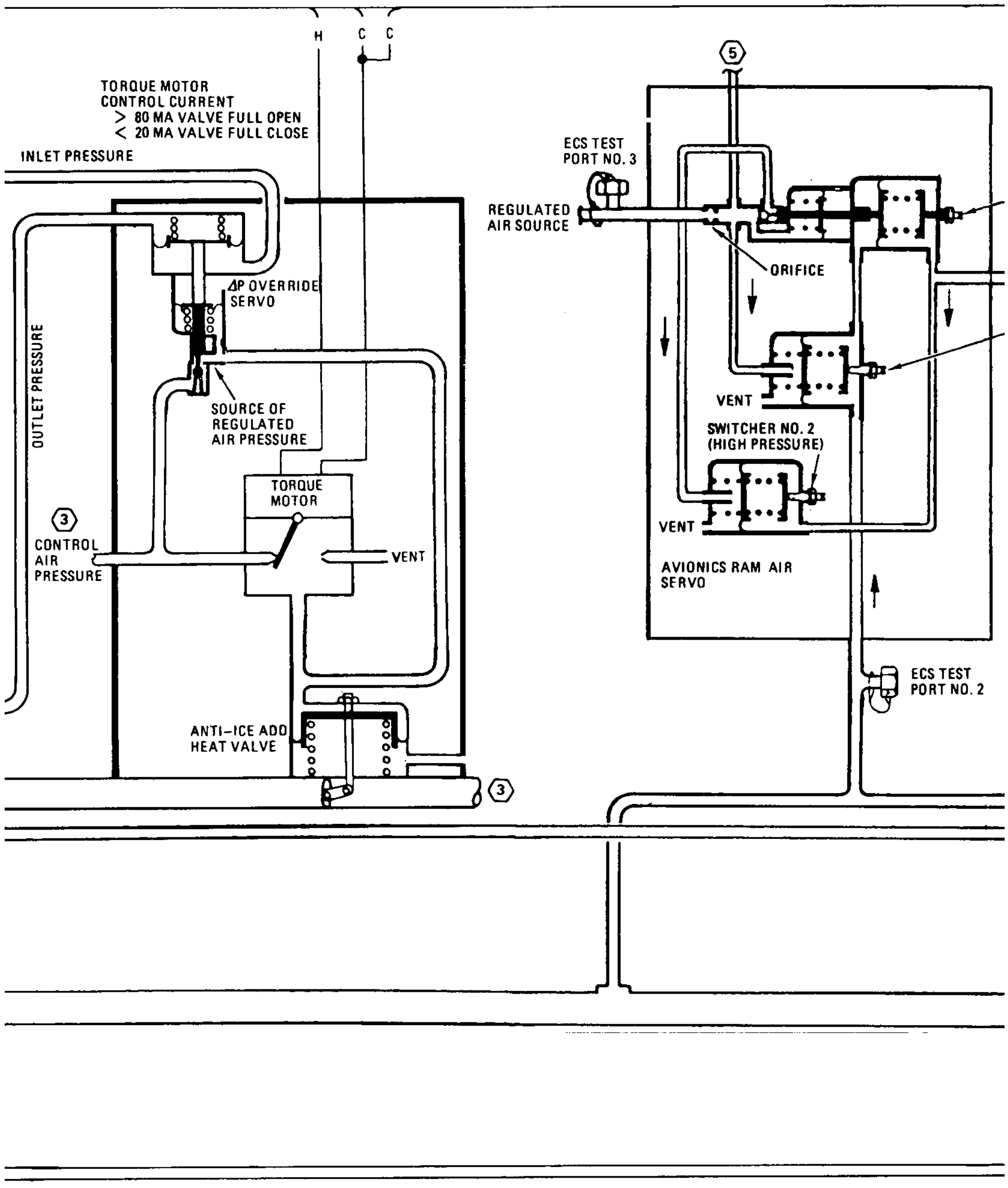


Figure 3-2B.—Air cycle air-conditioning system-Continued

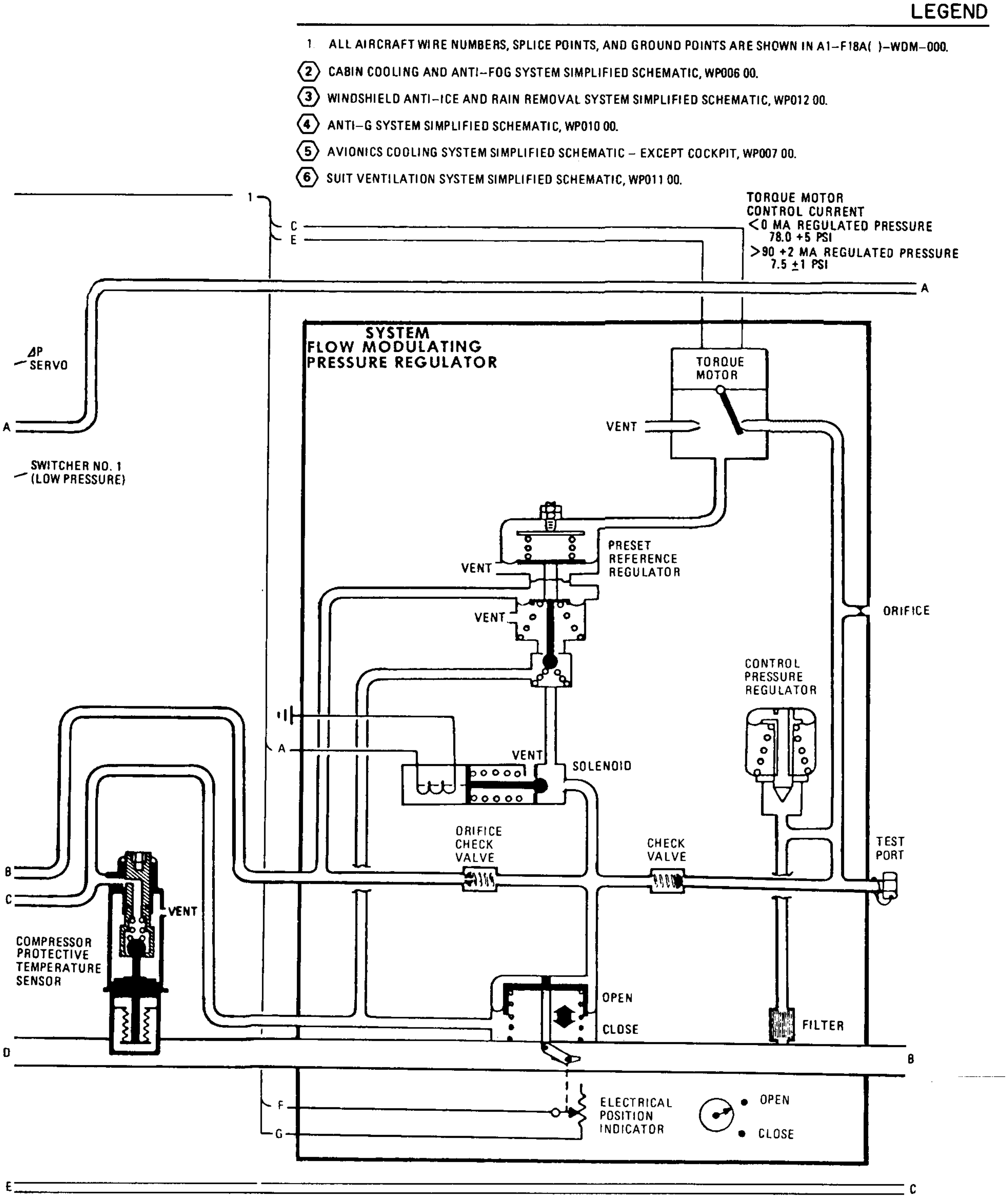


Figure 3-2C.—Air cycle air-conditioning system-Continued

7 FUEL PRESSURIZATION AND VENT SYSTEM SIMPLIFIED SCHEMATIC, A1–F18AA–460–100, WP009 00.

8 BLEED AIR SYSTEM SIMPLIFIED SCHEMATIC, WP004 00.

9 RADAR LIQUID COOLING SYSTEM SIMPLIFIED SCHEMATIC, WP013 00.

10 GROUND POWER SWITCHING SIMPLIFIED SCHEMATIC, A1–F18AA–420–100, WP005 00.

11 AIR DATA COMPUTER SYSTEM SIMPLIFIED SCHEMATIC, A1–F18AA–560–100, WP003 00.

12 MAINTENANCE STATUS DISPLAY RECORDING SYSTEM NON-AVIONIC MAINTENANCE CODES SIMPLIFIED SCHEMATIC A1–F18AA–580–100, WP003 00.

13 LANDING GEAR CONTROLLED RELAYS SIMPLIFIED SCHEMATIC, A1–F18AA–130–100, WP003 00.

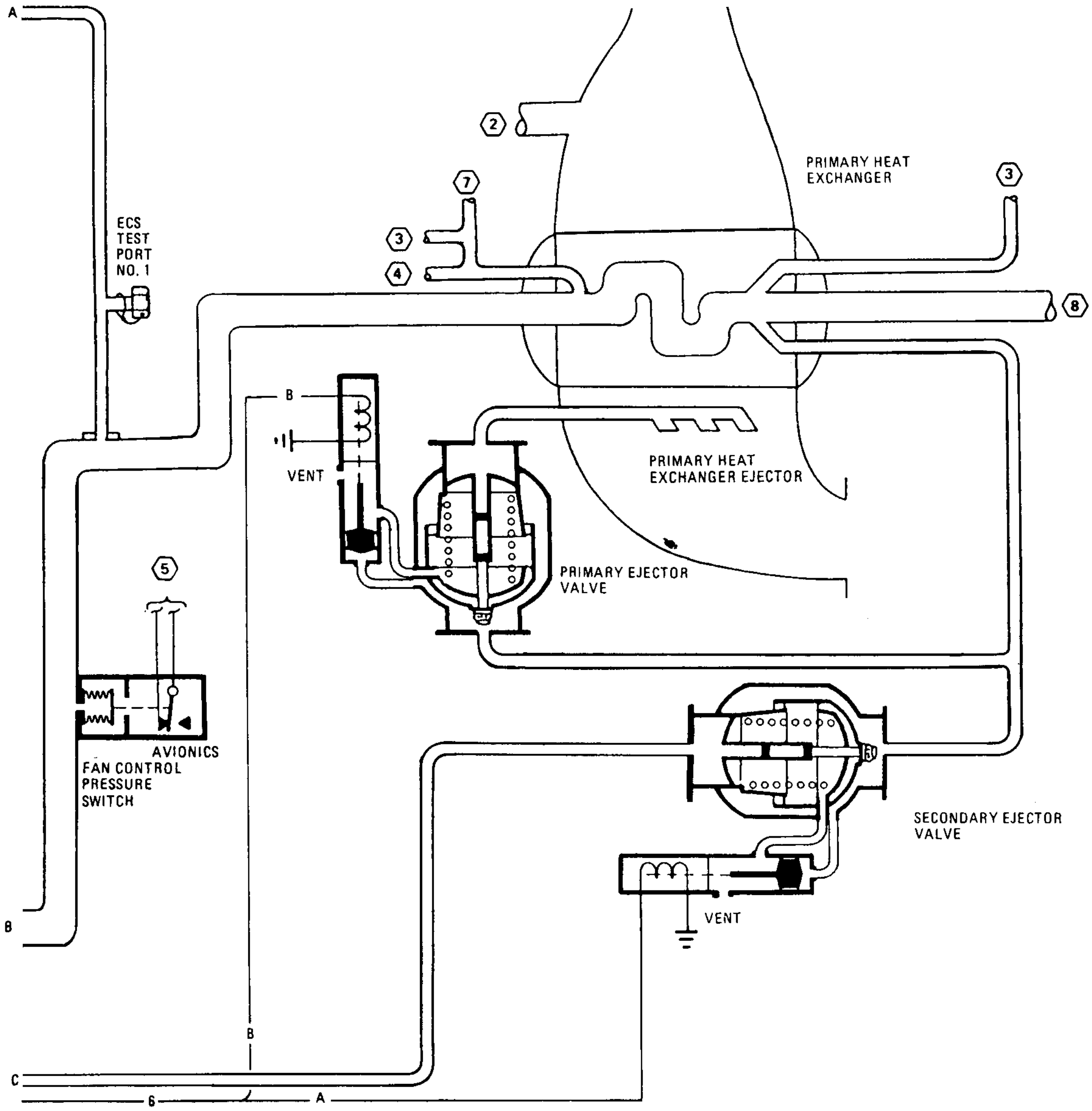


Figure 3-2D.—Air cycle air-conditioning system-Continued

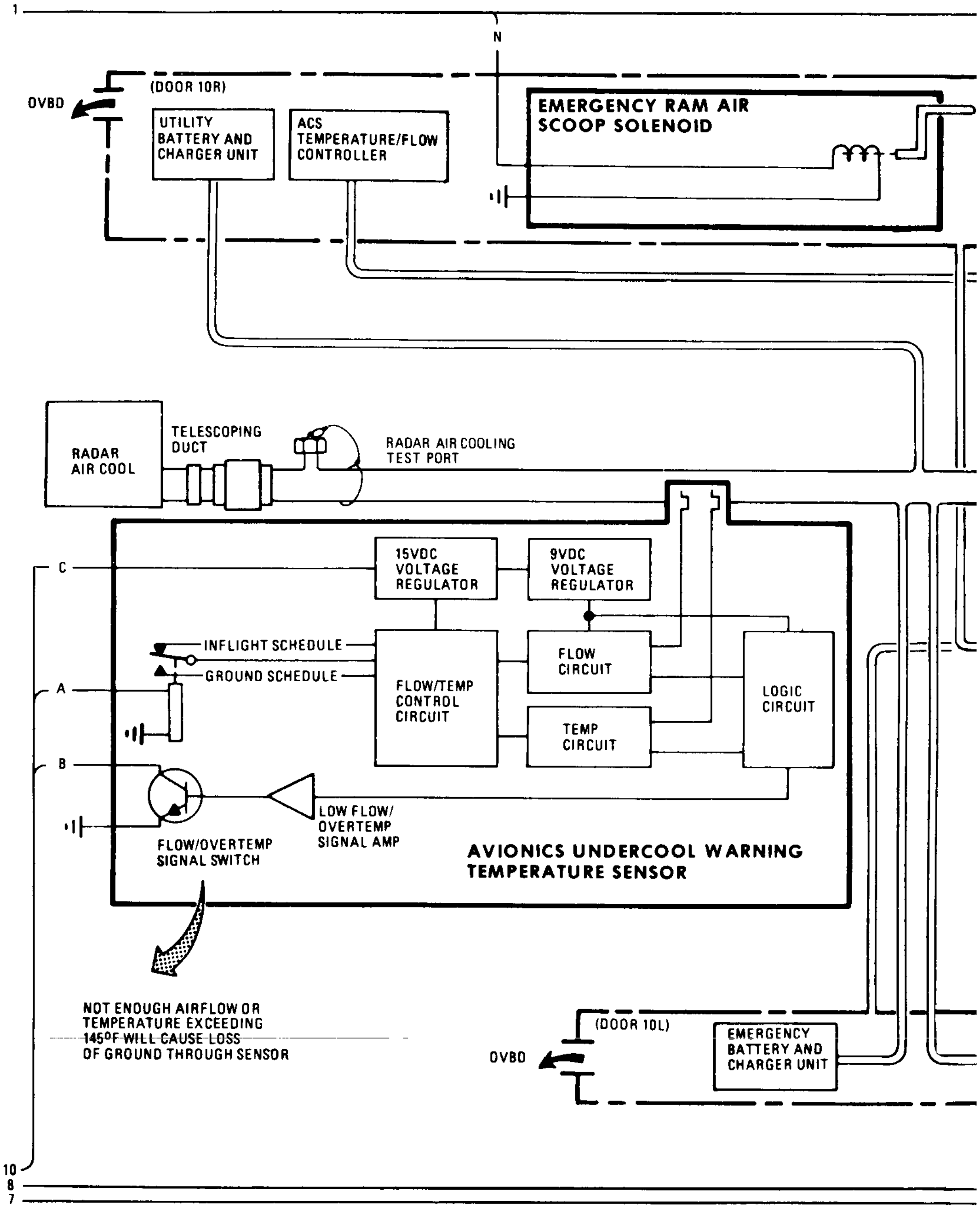


Figure 3-11A.—Avionics cooling system.

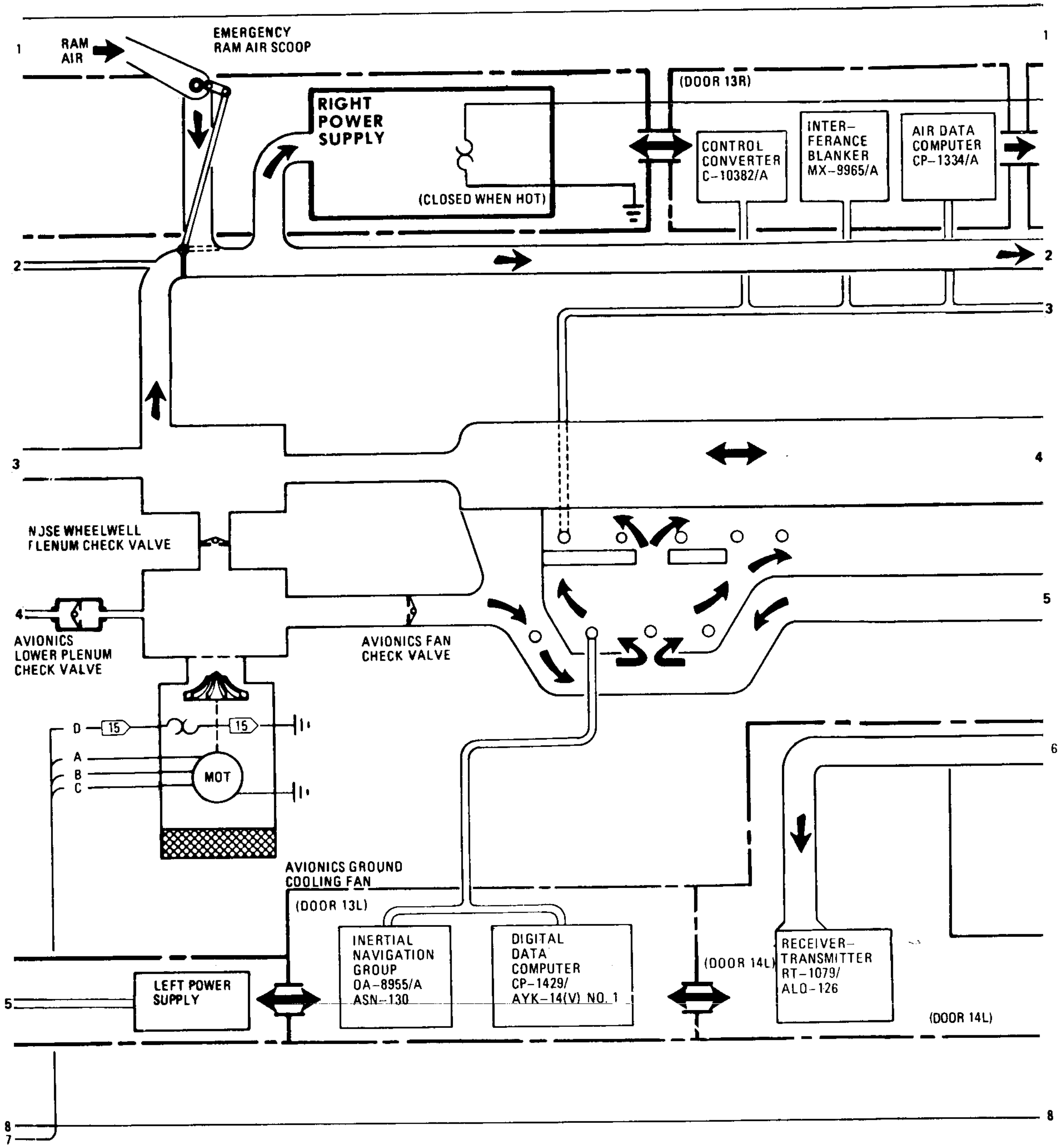


Figure 3-11B.—Avionics cooling system-Continued

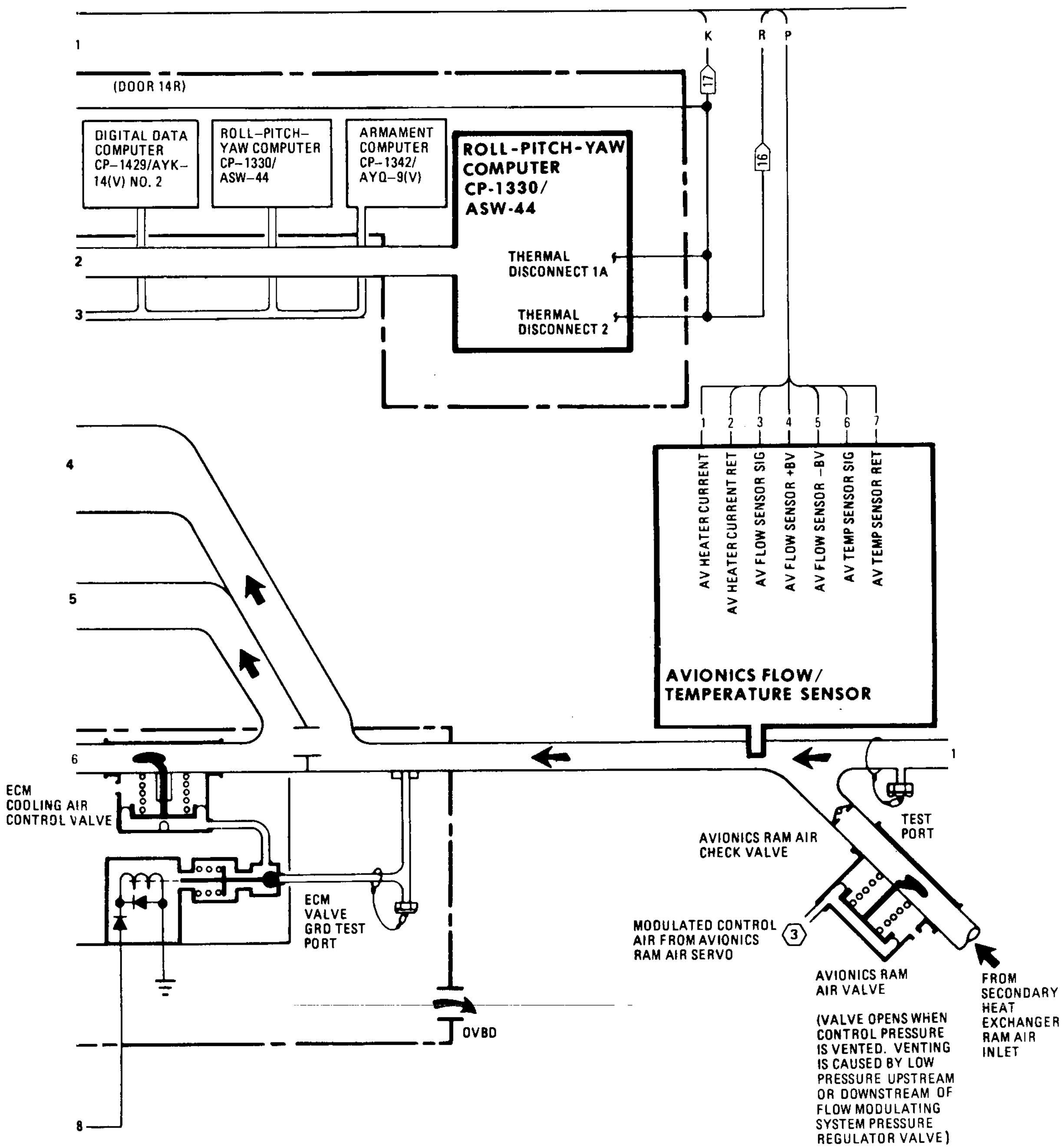
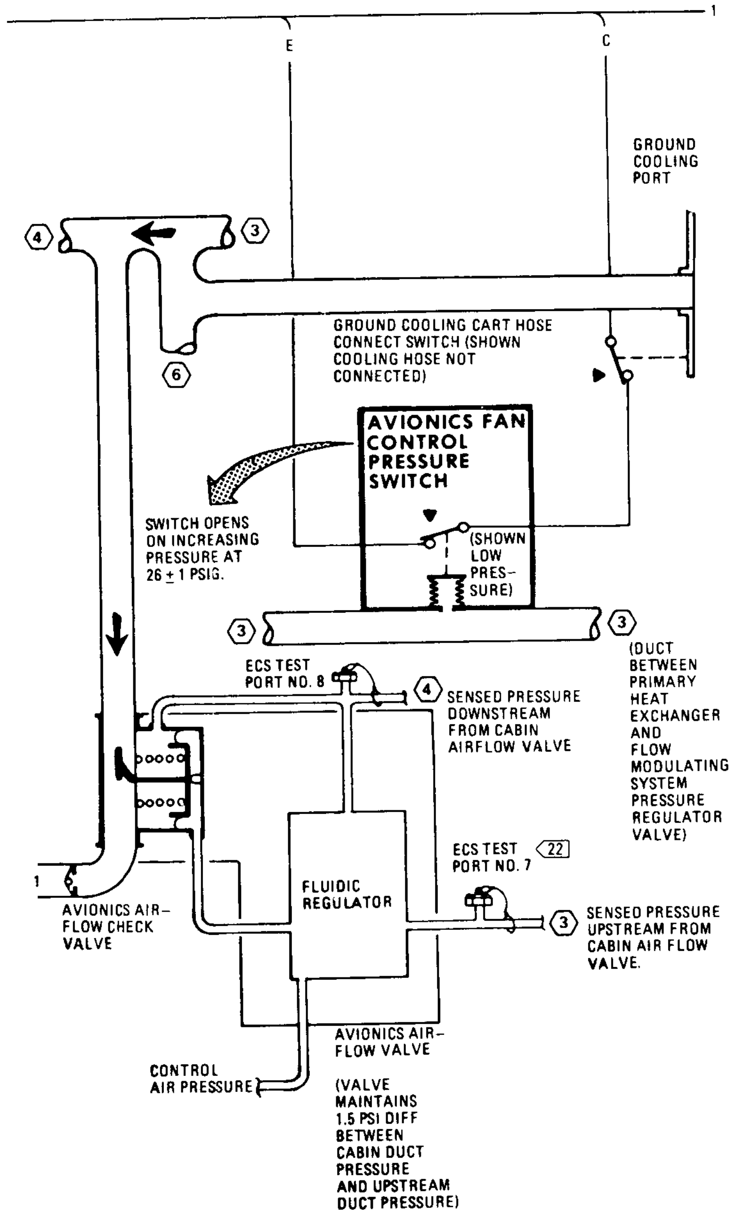


Figure 3-11C.—Avionics cooling system-Continued



LEGEND

1. ALL AIRCRAFT WIRE NUMBERS, SPLICE POINTS, AND GROUND POINTS ARE SHOWN IN A1–F18A( )–WDM–000.
2. GROUND POWER SWITCHING SIMPLIFIED SCHEMATIC, A1–F18AA–420–100, WP005 00.
3. AIR CYCLE AIR CONDITIONING SYSTEM SIMPLIFIED SCHEMATIC, WP005 00.
4. CABIN COOLING AND ANTI–FOG SYSTEM SIMPLIFIED SCHEMATIC, WP006 00.
5. AIR DATA COMPUTER SYSTEM SIMPLIFIED SCHEMATIC, A1–F18AA–560–100, WP003 00.
6. RADAR LIQUID COOLING SYSTEM SIMPLIFIED SCHEMATIC, 160777 AND UP, WP013 00.
7. COCKPIT WARNING/CAUTION/ADVISORY LIGHTING SYSTEM SIMPLIFIED SCHEMATIC, A1–F18AA–440–100, WP005 00.
8. MISSION COMPUTER SYSTEM SIMPLIFIED SCHEMATIC, A1–F18AA–741–100, WP003 00.
9. MAINTENANCE STATUS DISPLAY AND RECORDING SYSTEM SIMPLIFIED SCHEMATIC, A1–F18AA–580–100, WP003 00.
10. LANDING GEAR CONTROLLED RELAYS SIMPLIFIED SCHEMATIC, A1–F18AA–130–100, WP003 00.
11. BLEED AIR SYSTEM SIMPLIFIED SCHEMATIC, WP004 00.
12. CONTROL CONVERTER C–10382/A AND ELECTRONIC EQUIPMENT CONTROL C–10381/ASQ INTERCONNECT SIMPLIFIED SCHEMATIC, A1–F18AA–741–100, WP003 00.
13. AIR CONDITIONING SYSTEM BIT STARTS WHEN ELECTRIC POWER IS APPLIED TO THE ACS TEMPERATURE/FLOW CONTROLLER. INFLIGHT BIT IS A COMPLETE SEQUENCE OF TESTS ON THE ACS TEMPERATURE/FLOW CONTROLLER AND TEN ELECTRICALLY INTERFACING COMPONENTS. NINE SECONDS IS REQUIRED FOR A COMPLETE BIT SEQUENCE, AND THE BIT SEQUENCE IS REPEATED EVERY NINETY SECONDS. IF THE SAME TEST INDICATES A FAILURE ON 2 CONSECUTIVE BIT SEQUENCES, THE BIT PROCESSOR REMOVES A GROUND FROM SIGNAL DATA CONVERTER CV–3493/ASM–612, AND A MAINTENANCE CODE IS RECORDED. AFTER A MAINTENANCE CODE IS RECORDED, BIT IS INHIBITED UNTIL ELECTRICAL POWER IS REMOVED AND REAPPLIED. WHEN THE AIRCRAFT IS ON THE GROUND, BIT OPERATION IS THE SAME AS INFLIGHT BIT EXCEPT THAT ONLY A PARTIAL BIT SEQUENCE IS DONE.

Figure 3-11D.—Avionics cooling system-Continued